THE CHILD AS A REALISTIC SCIENTIST: DEVELOPING THE ANALOGY BETWEEN SCIENCE AND COMMONSENSE

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This work is dedicated to my grandfather, the late George King Nicolson, who inspired me from an early age with his love of learning and his ability to impart knowledge to others.

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Abstract

The proposal that there are important parallels to be drawn between children's cognitive development and the development of knowledge in science, has prompted a growing interest in the idea that in their interactions with the world young children can be profitably viewed as intuitive scientists. This study sets out to investigate the metaphor of the child as an intuitive scientist by undertaking a detailed examination of both science and children's commonsense thought, and in so doing, demonstrate the utility of the metaphor for developmental inquiry. Chapter 1 addresses the nature of science and the importance of selecting an appropriate model of scientific rationality as the basis for assessments of childhood thought. A realist theory of science is adopted as the most adequate account of scientific inquiry and hence the most appropriate framework with which to pursue child-scientist comparisons. Chapter 2 turns to lay cognition and looks to establish the theoretical status of folk psychology in light of recent claims that a theory is not necessary for comprehending human action. In Chapter 3 the focus turns to young children's knowledge and the question of correspondences with scientific thought. Research detailing the child's development of an understanding of mind is highlighted, indicating that in both the content of their knowledge and in the processes by which such knowledge is advanced, children bear a striking resemblance to scientists. Having demonstrated the plausibility of the child-as-scientist metaphor, Chapter 4 looks at ways to further develop child-scientist comparisons in order to achieve a valuable perspective on knowledge acquisition in childhood. Existing approaches to developing the metaphor are evaluated and in light of their limitations an alternative formulation is drafted, which argues that a focus on children's methods of inquiry informed by a realist perspective on science, constitutes the most profitable approach to developing the child-as-scientist metaphor. This study concludes that the metaphor of the child as an intuitive scientist with 'science' understood in realist terms, is a plausible metaphor for developmental inquiry to pursue. More specifically, by refocussing child-scientist comparisons at the methodological level and drawing on a comprehensive theory of scientific method to inform such comparisons, this study provides some directives as to how such a research program might best proceed.

" . . . one might argue that institutionalised science itself is simply a specialised form of a more general epistemological project that we are all engaged in from infancy."

Alison Gopnik, 1990

Introduction

During childhood, in particular the first five years of life, there occurs a veritable watershed in the development of children's understanding about themselves and about the world in which they live. Questions concerning how best to characterise this development, have sustained research interest since Piaget's investigations were published in 'The child's conception of the world'.* Nearly 60 years on, psychologists continue to focus on many of the same developmental phenomena that so intrigued Piaget. Increasingly however, the research literature has witnessed a move away from Piagetian descriptions of development in terms of a fixed set of cognitive states, and towards an emphasis on viewing conceptual development in children as analogous in many respects to the growth of knowledge in science. For some researchers, this proposed science-commonsense relation has entailed an appeal to theoretical knowledge structures as a useful source of information regarding the ways in which children's commonsense knowledge is organised (Carey, 1985b; Wellman, 1990). Others have found it attractive to view cognitive development as a process of theory formation, similar to the process by which understanding is advanced in science (Karmiloff-Smith, 1988; Gopnik, 1993). Within this framework, the metaphor of the child as an intuitive scientist has emerged as a profitable way of conceptualising children's interaction with the world and their development of knowledge.

This study sets out to investigate the hypothesis underlying the child-as-scientist metaphor, namely that there are important parallels to be drawn between children's cognitive development and the development of knowledge in science. By drawing these parallels this work will attempt to demonstrate the utility of this metaphor in advancing our understanding of the processes by which children learn about the world.

With this goal in mind, it would seem useful to begin by briefly situating the child-as-scientist metaphor within a broader theoretical context. Indeed, this shift in the developmental literature which looks to draw informative parallels between children's knowledge acquisition and science, is perhaps best interpreted as part of a more general change in research attitude towards the layperson and their

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* Originally published 1926 - 'La représentation du monde chez l'enfant'. Paris: Alcan. First published in the English language 1929 - London: Routledge & Kegan Paul.

capacity for reasoning. A dominant perspective in psychology has for a number of years served to promote the view that laypeople are poor or ineffectual problem solvers who display numerous biases in their everyday attempts to reason about the world (Kahneman, Slovic & Tversky, 1982; Nisbett & Ross, 1980). Within this tradition, researchers investigating people's inferential strategies have typically concentrated on an explication of these biases, appealing to normative models in order to expose the lack of fit between such models and everyday judgement (see Gigerenzer et al (1989) for a case study of the 'judgement under uncertainty' research program headed by Daniel Kahneman, Paul Slovic and Amos Tversky, in which the majority of research energy has been channelled into explaining discrepancies between human reasoning and probability theory).

This method of studying lay cognition by focusing on inferential *errors,* is predicated on the assumption that the nature of the human cognitive machine is best revealed through an examination of the defects or "program errors" it produces (Nisbett & Ross, 1980). However as Kahneman, Slovic & Tversky (1982) acknowledge, in the construction of an 'error focused' research program, 'the method' has to a large extent come to determine 'the message' regarding our natural capacity for rational thought. Investigations arguing for example that children and lay adults retain commitments to ideas in the face of disconfirmatory evidence (Kuhn, 1989), overestimate the causal role of dispositional factors in matters of social judgement while underestimating the contribution of situational factors (Ross, 1977), fail to reason in accordance with the principles of Bayesian inferential statistics (Kahneman, Slovic & Tversky, 1982), and generally display a strong bias for verification in their everyday attempts to comprehend the world (Wason & Johnson-Laird, 1972), have not surprisingly, resulted in an unflattering portrait of the layperson as reasoner. Compared with the rational reasoning strategies typically attributed to scientists, laypeople have been diagnosed with multiple inferential shortcomings, and as a consequence of these shortcomings seen to fall prey to irrational and error-prone judgements in their commonsense dealings with the world.

Recently however, this negative perception of the layperson has begun to change (e.g. Holland et al, 1986). A growing consensus on commonsense cognition spanning the disciplines of developmental and social psychology, cognitive science, artificial intelligence, and philosophy of science, now indicates that given the 'tools' we might reasonably expect are required, laypeople (both children and lay adults) perform very well in problem solving tasks and are generally adept at extracting information from their surroundings. This move towards a more optimistic view of lay rationality is perhaps best seen by looking across a range of recent studies on children's everyday problem solving. In these studies, researchers have diverged from the common practice of measuring lay judgment against normative models of statistical or logical inference, and instead looked to examine the strategies that *are* available to children for comprehending the world. Findings provide good cause for optimism regarding our natural inferential capacities, since they indicate that even very young children demonstrate the ability to reason causally (Brown, 1990), make valid inductive inferences (Gelman & Markman, 1986), develop their knowledge of poorly understood phenomena via analogical extension (Vosniadou, 1989), differentiate and coordinate ideas and evidence in an appropriate fashion (Sodian et al, 1991), and draw on a range of meta-conceptual criteria to appraise the explanatory coherence of competing explanations (Samarapungavan, 1992). More generally, children have been found to display powerful theory formation abilities, which allow them to simplify and unify incoming information into coherent conceptions and thereby obtain a representational 'handle' on the world (Gopnik & Wellman, 1992; Karmiloff-Smith, 1988; Vosniadou & Brewer, 1994).

Collectively, these studies can be seen to provide support for the view that laypeople have the capacity for complex reasoning, since they indicate that even young children have at their disposal a range of effective strategies for making sense of phenomena. This revised estimation of the layperson as a methodologically adept creature, is further promoted in the work of Holland et al (1986). In their attempts to construct a systematic approach to the study of induction, these authors present a theoretical framework that treats everyday problem solving and scientific discovery as fundamentally the same sort of process, to be explained in terms of rule based mental models. Discussing learning in scientific and everyday contexts in this manner, by utilising a *common* interpretative framework, not only serves to raise the perceived rationality of commonsense thought, it simultaneously demands a reassessment of the traditionally accepted division of science and commonsense. In turn such a reconceptualisation of lay cognition, paves the way for potentially informative parallels to be drawn between children and scientists.

It is with the intention of drawing these parallels that this study begins in Chapter 1 by addressing the nature of science and the importance of choosing an appropriate model of scientific rationality as a 'standard' for children's thought. In the main, researchers investigating child-scientist relations have, it will be argued, failed to give adequate attention to the account of science underlying their arguments. This is despite the fact that the model of scientific rationality operating in these studies effectively determines subsequent estimations of children's capacities for rational thought. Recognising that the validity of conclusions regarding children's competencies depends crucially on the validity of the scientific framework invoked however, demonstrates the necessity of addressing this imbalance in the developmental literature. The rationale for Chapter 1 then, is firstly to determine the account of science that has to date undergirded researchers' estimations of children's capabilities, and secondly to assess its suitability as an appropriate framework for child-scientist comparisons.

On investigation, it is argued that an empiricist account of science forms the predominant framework in evaluations of the scientific nature of children's thought. By way of appealing to contemporary commentary in the philosophy of science, an attempt will be made to highlight the deficiencies inherent in this philosophical framework, most notably its failure to provide a realistic account of scientific inquiry, and hence its unsuitability for the role of scientific standard in the child-as-scientist debate. Rejecting the scientific basis utilised by the majority of developmentalists in their investigations, demands that an adequate alternative be supplied. This is provided in this study in the form of a realist account of science, known as "Evolutionary Naturalistic Realism". The remainder of the chapter looks to outline this theory of scientific endeavour, and in so doing sketch an appropriate philosophical base for the treatment of the child-as-scientist metaphor which is to follow.

With an appropriate scientific framework in place, Chapter 2 turns to lay cognition and the question of similarities with scientific thought. In this chapter, an effort will be made to establish the theoretical status of our everyday psychological understanding or folk psychology as a necessary precursor to arguing that theoretical knowledge is common to children and scientists alike. This involves resisting two dominant challenges that have been mounted against the proposal that our folk psychological understanding constitutes a genuine empirical theory. The first body of criticism argues that in terms of both its structure and the way in which it functions in everyday life, folk psychology fails to correspond with theories in science. Working from a realistic perspective on scientific inquiry however, it will be suggested that such criticisms can be seen to stem from an inappropriately narrow rendering of theory, supported by a tacit commitment to an empiricist view of science. In attempting to disarm such a challenge, folk psychology is seen to be unveiled as a commonsense theoretical framework, whose status as a theory is arguably justified by its explanatory and predictive success in the everyday domain in which it functions.

The second dominant challenge to the theory view, takes the form of an alternative account of our everyday psychological knowledge. On this account, a 'theory' is deemed unnecessary for comprehending human action, since in looking to explain and predict each other's action it is suggested that we simply draw on the resources of our own minds to 'simulate' the workings of others. By undertaking a comparative evaluation of these two theoretical explanations along a number of dimensions however, a case will be made for the claim that simulation theory does not constitute a direct challenge to the theory view of folk psychology. Rather, it will be argued that simulation is best perceived as a skill or capacity, which is insufficient in itself to provide explanatory understanding, but when conjoined with other strategies enables us to acquire a commonsense theory of mind.

Having looked to establish an appropriate scientific framework within which to situate child-scientist comparisons, and to indicate the theoretical nature of our commonsense model for understanding human action, the focus shifts in Chapter 3 to young children's knowledge and the extent to which comparisons can be made between the young child and the scientist. Recognising that the child-as-scientist metaphor embodies a perspective on children's knowledge construction abilities which diverges sharply from traditional depictions of children's thought, a primary concern of this chapter is to discover whether in light of recent developmental research the metaphor can be maintained. Drawing on a comprehensive body of literature detailing the child's development of an understanding of mind, evidence will be highlighted which indicates that general parallels do exist between children and scientists in terms of both the theoretical nature of their knowledge and the process by which such knowledge undergoes development.

Having sought to establish the plausibility of the child-as-scientist metaphor by addressing the nature of science, the nature of lay cognition, and the nature of childhood thought, Chapter 4 looks to analyse the implications of this metaphor for the development of knowledge in science. Accordingly, the chapter will begin with a consideration of how child-scientist relations have been developed to date, in terms of parallels between the growth of knowledge in children and the growth of knowledge in the history of science. Attention in this section is given to two different approaches to developing the child-as-scientist metaphor via 'history-of-science' comparisons, and limitations of each are highlighted.

Following this critical evaluation, a reconceptualisation of the metaphor will be undertaken in which it is argued that a focus on the methods of inquiry utilised by children informed by a realist perspective on science, constitutes the most profitable approach to developing the child-as-scientist metaphor. A general theory of scientific method consistent with Evolutionary Naturalistic Realism is outlined for this purpose, and compelling similarities between children's methods of inquiry and this realistic account of scientific endeavour are brought to the reader's attention. Given these similarities, this study concludes that the metaphor of the child as an intuitive scientist with 'science' understood in realist terms, provides researchers with an informative characterisation of cognitive development. More specifically, by refocussing child-scientist comparisons at the methodological level, this work indicates the potential of drawing on a comprehensive theory of method designed to illuminate the process of knowledge advance in science, to promote our understanding of how children learn.

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The nature of science Establishing an appropriate framework

Comparisons in the literature between children and scientists have generally speaking been disproportionate in their analyses. That is, in comparing children's problem-solving strategies with the processes operative in scientific discovery, few researchers have explicitly acknowledged the general account of science they are working from. Effectively, science has been taken as a 'given' in the equation, functioning as a fixed standard of rationality against which to assess children's reasoning.

However, examining the nature of science would seem crucial to any serious analysis of the child-as-scientist model, since adherence to a particular model of science will largely determine one's perspective on the character of childhood thought. *The importance of choosing an appropriate model of scientific rationality is therefore tantamount to the validity of research in this field.* For as Byrnes (1993) points out, if the standard used to assess the quality of thinking in childhood is questionable, then any process of comparison that rests on this standard, is essentially misguided.

This study of the child-as-scientist metaphor takes as its point of departure the assumption that any assessment of knowledge development in children necessarily includes an assessment of the scientific standards by which we judge their knowledge. Accordingly, Chapter One will seek to address the following issues. Firstly, attention will be given to outlining how an empiricist account of science has underscored arguments in the child-as-scientist literature, and how its inadequacy in capturing the reality of scientific practice makes it an unsuitable philosophical framework for research in this area. Having rejected an empiricist framework, consideration will be given to a realist account of science, specifically Evolutionary Naturalistic Realism as championed by Hooker (1987). This alternative view is adopted in this study as the most realistic portrayal of scientific endeavour and hence as the most appropriate philosophical base from which to examine similarities between children and scientists.

1.1 The child as scientist : current characterisations

The idea that science has the potential to provide a 'window' on cognitive development, has propelled researchers to investigate the ways in which children can be seen as intuitive scientists. As a result, two important aspects of scientific endeavour have emerged as focal points of interest in the child-as-scientist debate. The first, concerns the fact that knowledge in science inheres in *theories.* Traditionally, a sharp distinction has been drawn between theoretical and non-theoretical knowledge, with childhood thought falling squarely in the latter category. Recently however, a growing number of psychologists have persuasively argued that children possess coherent bodies of knowledge that bear marked resemblances to theoretical structures in science. The concern in these investigations then, is with the *content* of children's knowledge and whether it is conceivable that children be credited with something akin to a scientific theory.

The second aspect of scientific endeavour lending itself to comparison with children's thought, concerns the *methods* by which knowledge is generated in science. While much debate has focused on the theoretical status of children's knowledge, far less research attention has been directed towards examining possible similarities between children and scientists in terms of the process of knowledge construction. Such reluctance is not surprising given the traditional conception of the objective scientist who operates by applying the laws of formal logic; a depiction of scientific inquiry which seems far removed from the everyday problem solving activities of the young child. However, an increasing concern with how scientists do operate in their day to day practice, together with micro-developmental studies of knowledge formation in children, has led some researchers to suggest that the commonsense methods of inquiry children demonstrate are analogous in many respects to the processes employed to promote scientific discovery.

A concern with scientific theories and scientific method then, constitute two important ways in which the child can potentially be viewed as an intuitive scientist. In debating these two analogies between science and commonsense however, researchers have given scant attention to the general account of science underpinning their arguments. Essentially, specific ideas regarding theories and scientific reasoning have been imported into the child-as-scientist debate, without any consideration of the wider philosophical framework on which they depend. Here an outline of the child-as-scientist literature will be given in an attempt to situate the characterisations of theories and scientific method within a more general account of science, and so better appreciate the scientific standards underlying researchers' evaluations of children's knowledge.

1.1.1 Scientific theories

The slogan 'children's theories of mind' has come to identify a body of psychological research that draws on the notion of a theory in order to explicate children's development of an understanding of mind. According to this view, the young child's ability to attribute mental states such as beliefs and desires to themselves and to others as a way of making sense of behaviour, is dependent on an implicit theory which is formed somewhere between the ages of 3 and 5 years. While a 'theory perspective' on children's psychological knowledge has become a dominant view in developmental psychology, the widespread application of the 'theory-of-mind' slogan is, as Astington and Gopnik (1991) point out, also a reflection of the fact that 'theory' is used by many researchers as a catch-all term for any organised body of knowledge. As a result much of the current debate concerning the theoretical account of children's understanding is hopelessly imprecise, to the extent that different researchers appear to be drawing quite different conclusions when they impute a theory to the young child.

Some researchers (Gopnik, 1990; Perner, 1991; Wellman, 1990) have responded to this situation by arguing for a stronger, more highly structured notion of a theory, that draws close analogies between scientific theories and children's folk psychology. However, as Wellman (1990) points out, this task is made difficult by the lack of consensus concerning the nature of scientific theories in philosophy of science. Because questions surrounding an appropriate portrayal of scientific theories remain unresolved, different researchers have tended to focus on different features to support their views. Of interest to this study is the marked division on the question of what characterises scientific theories between those who argue for the theoretical account of children's understanding, and those who endorse a contrasting non-theoretical account such as simulation. For these two opposing camps the so-called "defining features" of scientific theories vary in significant ways.

Of those who endorse a developmental version of the "theory-theory" (Morton, 1980), namely the view that our folk psychological understandings comprise a theory, Wellman (1990) provides the most concerted attempt to define the nature of the relation between commonsense understanding and scientific theories. Borrowing from the philosophy of science he argues that three criteria must be met in order to justify the use of the term 'theory'. Firstly, theories in science are seen to be characterised by a type of *coherence* that serves to distinguish them from other forms of knowledge. Theories are not simply a loosely grouped bunch of facts or beliefs, rather they demonstrate a unity or interconnectedness, whereby the concepts or theoretical terms encompassed by the theory are more or less defined by their place in a web of constructs. Other researchers advocating the theory-of-mind view similarly emphasise coherence as a characteristic feature of scientific theories. For example Gopnik (1993) draws on the coherency of children's psychological understanding as an interlocking body of beliefs to endorse its theoretical status.

The second aspect of theories cited by Wellman, is that they specify the kinds of entities that exist in the domain in question. That is, theories necessarily include and rest upon specific *ontological distinctions or commitments.* For example our commonsense psychology effectively partitions the world into two ontologically distinct categories: the internal mental realm and the external physical realm. The importance of this feature to any characterisation of theories can, Wellman claims, be seen by considering how impossible it would be to argue that young children should be credited with a theory of mind, if they demonstrate no appreciation of the basic ontological distinction between 'mind' and 'matter'.

Thirdly, Wellman proposes that a theory invokes and provides us with "a causal-explanatory framework to account for, make understandable, and make predictable phenomena in its domain" (1988, p.66). That a theory supplies us with a *causal-explanatory scheme* with which to understand the domain in question, is according to Wellman, fundamental to even the most basic notion of a theory. While often not defining this feature in explicit terms, most researchers endorsing the theory view would seem to agree, pointing to the ways in which children utilise their folk psychological knowledge to explain and predict people's actions in order to support their arguments for a theory of mind.

The three features highlighted by Wellman serve to provide us with an initial conception of how scientific theories are conceptualised by those researchers who argue that the young child should be credited with a theory of mind. However, Wellman (1990) gives further definition to his theoretical characterisation of children's knowledge, by suggesting that our commonsense understanding of mind is best viewed as a *framework* theory.

In contrast to specific conceptual structures, large scale or framework theories can be seen to deal with more global concerns. Put simply, they serve to frame specific theories by defining a domain including its ontology, the causal devices in operation, as well as providing some constraints on what will feature as a legitimate methodology. Another characteristic of framework theories important to Wellman's argument is that they are relatively protected from empirical test. While specific theories find themselves exposed to the possibility of empirical refutation, the grounding assumptions underwriting such theories usually only come under scrutiny in revolutionary periods of science, which witness the complete overhaul of a framework or theoretical tradition and its replacement with a superior alternative. Many philosophers have highlighted the significant role these large scale theories play in science, variously referring to them as 'paradigms' (Kuhn, 1970), 'research programmes' (Lakatos, 1970), 'global theories' (Hooker, 1975), and 'research traditions' (Laudan, 1977). Examples of framework theories include Newtonian mechanics in physics, evolutionary theory in biology, and cognitivism in psychology.

In Wellman's view, the most appropriate level at which to compare children's psychological knowledge with scientific knowledge is at the level of framework theories; indeed, it is in this sense that he conceives our everyday psychological understanding as comprising a theory of mind. Like its framework theoretical counterparts in science, folk psychology can be characterised in terms of its global features; that is, as constituting an ontology (the mind), a causal-explanatory infrastructure (belief-desire reasoning), and as providing a framing device within which to house more specific conceptual structures. More generally, by indicating the importance of global theories to the scientific enterprise and by arguing that children also endorse framework theories in their everyday endeavours, Wellman highlights a significant way in which children are like scientists.

A very different characterisation of scientific theories emerges in the work of those researchers who reject a theoretical account of children's psychological understanding. Harris (1989) and Johnson (1988) for example, argue that it is implausible to talk of the child possessing an implicit theory. While they accept that in some "trivial" sense all knowledge is theoretical knowledge, both researchers view the stronger analogy between children's psychological understanding and scientific theories, to be misguided. Children do genuinely learn about the mind according to Harris and Johnson, but this knowledge is best described as 'intuitive' rather than 'theory-like'.

What features of scientific theories are called upon to support this blanket rejection of the analogy between theoretical knowledge and children's understanding? In contrast to Wellman's concern with the global features of folk psychology that are suggestive of its framework theoretical status, those opposing the theory view of mind focus on the explicit nature of scientific theories; the fact that they are used by scientists in their attempts to order evidence, as opposed to operating implicitly; and that they are compiled by a process of stringent formalisation and testing peculiar to institutionalised science.

The most prominent feature of scientific theories alluded to by those rejecting the theoretical view of children's understanding, concerns their *formal structure*. Theories on a mathematical model have traditionally been viewed as comprising an axiomatic system where the theoretical postulates are connected in a lawful manner with statements about observable phenomena via various correspondence rules. On this characterisation then, scientific theories are seen to be very different sorts of structures to the cognitive structures encompassing children's commonsense psychological understanding.

1.1.2 Theories and theorising : dividing 'content' from 'process'

Up to this point, scientific theories have been considered from rather a static point of view; the resulting characterisation being one of an entity or fixed knowledge structure. However, one of the most important aspects of theories is surely that they undergo development - a quality not captured by the 'entity' characterisations outlined above. Gopnik and Wellman (1992) address this imbalance in the literature by proposing that any meaningful characterisation of scientific theories necessarily involves consideration of the more dynamic, procedural aspects of theories, namely those processes involved in theory formation and change.

In their 1992 paper entitled "Why the Child's Theory of Mind Really Is a Theory", Gopnik and Wellman turn their attention to theory change. While not providing a prescription for such change, these researchers suggest that certain "characteristic intermediate processes" can be discerned in the work of scientists, who are involved in the transition from one theory to another. Briefly stated, theory change will often be preceded by an accumulation of evidence that runs counter to the theory in question. Initially, the importance of attending to such counter examples may be denied, and the evidence ignored. Eventually the need to account for such evidence will be acknowledged, often by developing various auxiliary hypotheses to deal with the specific anomalies at issue. Such auxiliary hypotheses however are cumbersome and over time rob the theory of its earlier simplicity or elegance. A final step in the transition involves the construction of an alternative view to the original theory, which may at first be applied in a relatively limited manner, and only later recognised to provide a coherent account of both the anomalies and the evidence explained by the earlier theory.

Despite the possible advantages accrued from utilising what appears to be a more meaningful characterisation of scientific theories, the majority of researchers seem decidedly unwilling to consider similarities between scientists and children in terms of the *process* by which their respective theories are revised. That is, of those who endorse the theory view of mind, few it seems are also willing to credit the young child with the rationality of the scientist. Zaitchik and Samet (1993) to take one example, are prepared to accept that the child's understanding of mind be seen as a theory in some structural sense, but reject outright Gopnik's (1993) assertion that it is arrived at via a process of *theorising.* In their view, the child's theory of mind is neither refutable nor revisable, nor is it constructed from evidence.

Similarly, Deanna Kuhn (1989) accepts the possibility that both child and scientist may gain understanding of the world through theories, but claims that the analogy pertaining to the method/inquiry side of science is fundamentally misleading. The processes by which children and scientists go about exploring the world, generating and interpreting the data that will inform their mental models, are in Kuhn's view, not comparable. In short, this view indicates that while young children may well hold theories, such theories are divorced from any process approximating scientific reasoning. Just why researchers are committing themselves to the position that children form theories but do not utilise a similar method of theorising to scientists, would seem an important question to ask. And it appears that in part, the answer lies in a commitment to the commonplace empiricist view of what it is to do science.

1.1.3 Scientific Method

In her analysis of intuitive scientific activity, Kuhn (1989) explicitly denies that lay people demonstrate the forms of reasoning utilised by professional scientists. According to Kuhn, scientific thinking is essentially characterised in terms of the progressive differentiation and co-ordination of theory and evidence. Scientists demonstrate the ability to consciously articulate their theories; they evidence knowledge of the logical relation holding between theories and empirical data; they can distinguish what evidence provides support for the theory under examination and what evidence contradicts it; and they are able to provide justification for their acceptance of the theory in question in terms of its empirical adequacy. In contrast to performance by scientists, Kuhn cites findings indicating that these skills in relating evidence to theories are seriously underdeveloped in children and many lay adults. She concludes that children do not reason like scientists, rather scientific thinking processes follow a developmental path. In Kuhn's view it is the "*instruments* of scientific thinking, not just the products that undergo strong restructuring" (1989, p.688).

In making such claims, Kuhn seems to be working off an empiricist account of scientific method that promotes empirical testing and an appeal to logic as the hallmarks of scientific endeavour. To illustrate, Kuhn's standard of scientific method which she uses to assess lay thought, is constructed solely with reference to the justification of knowledge claims. There is no talk of the methods utilised by scientists in generating theories; nor of the processes by which newly generated theories are developed. In short, Kuhn appears to take a decidedly narrow view of what it is to do science, articulating her standard of scientific thought in terms of the processes operative in one subcontext of scientific inquiry. Moreover, within this narrow context, Kuhn assumes that scientists are exclusively involved in the process of revising their theories by subjecting them to empirical test. No consideration is given to viewing theory appraisal as a multi-criterial affair, in which theories are evaluated on more than merely their predictive accuracy.

Tied to her concern with testing for empirical adequacy as representative of the processes involved in scientific inquiry, is Kuhn's conceptualisation of scientific reasoning in terms of formal logic. Indeed her assessment of children as deficient reasoners seems to be based on the assumption that science functions by deploying special types of logical reasoning that are fundamentally distinct from the reasoning processes employed by nonscientists. Certainly the fact that the so called 'expert reasoners' in Kuhn's studies were Phd candidates in philosophy, provides some indication of the degree to which she views logical models of reasoning as constitutive of scientific thought.

A similar account of scientific method would seem to underlie claims by other researchers that the child is a 'nonscientist'. For example those opposing the theory view of mind (Harris, 1989; Johnson, 1988), do so in part because theories are seen to be compiled by a process of stringent formalisation and testing, peculiar to institutionalised science. Indeed this empiricist model of scientific inquiry appears to be so strongly adhered to, that even a researcher such as Wellman who emphasises the existence of theoretical knowledge in very young children, has in the past denied that this knowledge is acquired by a process similar to scientific theorising. In fact his proposal that the child's theory of mind be seen as a framework theory, appears motivated at least in part by the desire to avoid process considerations, and to reconcile his theory of mind claim with the following view:[1]

"Children do not craft their theories on the basis of explicit, rigorous activities akin to scientific formulation and test . . . most of our commonsense theories are acquired by processes of everyday knowledge acquisition in childhood. These processes are not well understood, but they surely are not the processes of formulation and testing employed in scientific theorising" (Wellman, 1990, p.130).

In sum, because of their commitment to an empiricist account of scientific endeavour, very few researchers are willing to credit the young child with the rationality of the scientist. Even Wellman who is committed to the theory view of mind, rejects the proposal that this knowledge is acquired by a process akin to scientific reasoning. In effect an empiricist account of scientific rationality operates in the majority of the child-as-scientist literature as a fixed uncontroversial standard against which children's thought is assessed and declared substandard. However the appropriateness of this scientific theory in providing a realistic account of scientific inquiry goes largely unquestioned.

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[1] This is despite the fact that there is a methodology component to such theories; a component which Wellman not surprisingly refrains from discussing.

1.2 Empiricist science : a questionable standard of scientific rationality

"The idea that mathematical or logical reasoning provides the paradigm of rationality goes back at least as far as Plato. And it was of course, the ideal of a logical system that provided a main inspiration for logical empiricism" (Giere, 1988, p.176).

As diagnosed in the previous section, the reluctance by many researchers to accept the child-as-scientist model can be seen to stem from their commitment to an empiricist account of science. Whether or not this is an appropriate account of scientific endeavour on which to base comparisons is an issue that remains untouched in the child-as-scientist literature. In this section an attempt will be made to tackle this question by turning to what philosophers of science have had to say regarding the capabilities of this theory in capturing the reality of scientific practice. The critical evaluation that follows is not intended as a full scale assault on logical empiricism (for a particularly clear extended critique see Hooker, 1987). Rather, attention will be focused on the features of this philosophical theory that are of particular relevance to the child-as-scientist debate.

1.2.1 Theories : Formal systems or cognitive tools?

The first point to be addressed concerns the empiricist account of a scientific theory as a formal logical system. Drawing on the foundations of mathematics as a model, logical empiricists developed a syntactic account of theories as structures comprising an axiomatic set of sentences in which theoretical postulates are connected in a lawful manner with the bedrock of statements about observable data via various correspondence rules. Construed in this way, as a collection of objective observation statements ordered by formal logic, theories were seen to hold the promise of delivering true descriptions of the world. The reluctance of a number of developmental researchers to credit children with theoretical knowledge can it is suggested be interpreted as stemming directly from an implicit commitment to this idealised empiricist conception.

While the problems inherent in the syntactic account of theories are well documented in the literature (for a detailed treatment see Suppe, 1974), there are certain criticisms that seem especially pertinent to the issues considered in this study. Firstly, a number of critics have commented that this view of theories bears little relation to how in fact theories are used by scientists in their day to day practice. Thagard (1988) argues that in order for an account of the nature of scientific theories to be practically adequate, it must be psychologically realistic; that is, it must accord with our understanding of how knowledge is structured in human minds. Likewise Giere (1988) indicates that the highly idealised description of scientific theories offered by the syntactic account, and indeed even the more sophisticated set-theoretic approach embraced by neo-empiricists (see van Fraassen, 1980), present only a stumbling block if our goal is to characterise the cognitive structures employed by real scientists. On reflection, it would seem that it is precisely this disparity between the standard account and the conceptual realities utilised by scientists that underlies Brewer and Samarapungavan's (1991) complaint that children's theories have been characterised as fragmented and imprecise because they have been inappropriately compared with the elegant formal reconstructions of theories within the institution of science.

Another problem with this empiricist construal of the structure of scientific theories is that it fails to deal adequately with the dynamics of theory development. Thomas Kuhn (1970) was instrumental in bringing this criticism to bear on the syntactic account of theories outlined above, by demonstrating that the empiricist belief that science is a cumulative enterprise is not true to the reality of intertheory relations reflected in the history of science. His emphasis on the diachronic aspects of knowledge as a reaction to the traditional neglect of conceptual change, is echoed in Gopnik and Wellman's charge to the majority of child-as-scientist researchers, that through their neglect of the procedural aspects of scientific theories, they are endorsing an historically inadequate scientific standard for the assessment of children's knowledge.

The empiricist conception of a scientific theory as a relatively fixed knowledge structure devoid of any 'epistemic life', is closely entwined with empiricism's official position on the role of theory in the scientific enterprise, that is as a convenient device for ordering observations. This instrumentalist view that takes theories to be merely organisational devices and denies them any referential role, has been criticised as woefully inadequate in portraying how theories actually function in science, most noticeably in its failure to appreciate the theory dependence of much of research practice (Hooker, 1975; Wylie, 1986).

1.2.2 Scientific Methods : distinct from everyday reasoning?

The mismatch that exists between theories as we find them in science and the abstract formalised empiricist characterisation, is even more marked when we turn to a consideration of scientific methods. Here we are confronted with an empiricist picture of the ideally rational scientist, who operates by applying the rules of formal logic to the objective facts. This traditional picture of knowledge production in science inspires little in the way of comparisons with children's thought. However, not only is this depiction of scientific inquiry far removed from the everyday problem solving activities of children, it would also seem at odds with what many philosophers regard as a realistic model of scientific rationality.

Firstly, consider reasoning. According to an empiricist account of scientific method, reasoning is construed solely in terms of logical argumentation, encouraging the equation of rationality with logicality. Indeed it is an acceptance of this equation that would seem to underlie Deanna Kuhn's assessment of children as deficient reasoners (Kuhn, 1989). The distinction between children and scientists is thus revealed as a perceived difference in rationality. But is this in fact the case? Such claims concerning the lack of scientific reasoning in children, are predicated on the assumption that scientists typically reason in a logical manner. However such an assumption has been vigorously contested in philosophy of science literature by Toulmin (1972), who emphasised the importance of the distinction between logic and rationality, and more recently by Giere (1988) and Thagard (1988).

Giere (1988) for example, argues that the view of scientific reasoning as properly restricted to formal logics, amounts to an a priori account of how scientists should think that fails to do philosophical justice to the reality of scientific investigation. His proposed solution is to forgo using the term 'rationality' altogether and simply talk about "human actions directed toward reaching specified goals" (1988, p.161). While this would seem an over-zealous reaction to the disparity between traditional philosophy of science and scientific practice, Giere's insight, namely that logic does not define the bounds of scientific reasoning, indicates that children are being inappropriately compared to a deficient conception of how scientists think. A more appropriate conception of 'right reasoning' would be one that does not deal exclusively with formal induction and deduction, but takes stock of other forms of reasoning important to scientific endeavour, such as abductive reasoning and reasoning by analogy. The resulting broadened account of rationality would in fact serve to highlight *similarities* between children and scientists, not dissimilarities, as both these forms of reasoning are also important to everyday inquiry.

Questions pertaining to the adequacy of the logical model of reasoning as a standard for children's thought, can be voiced with equal vigour against the received view of scientific method. Empiricism customarily employs the hypothetico-deductive account of scientific inquiry according to which theories, or more commonly singular knowledge claims, are tested in an indirect manner by deducing from them consequences which can then be subjected to direct empirical test. Under hypothetico-deductivism, the testing of hypotheses for evidential adequacy is where science proper begins . . . and ends. All other aspects of inquiry are either neglected entirely, or seen to be located outside the realm of science. It is this account of scientific method which can be seen to underlie Deanna Kuhn's concern with the differentiation of theory and evidence in analysing intuitive scientific activity, and her conclusion that children (and lay people generally) are *novice* reasoners (Kuhn, 1989).

In subscribing to hypothetico-deductivism however, Deanna Kuhn is endorsing a number of grounding assumptions of this theory of method which have been soundly criticized in the philosophy of science literature (see for example Glymour, 1980). For example, her claim that children and lay adults do not differentiate theory and evidence and hence are inferior reasoners, is based on the assumption that 'theory' and 'evidence' are in fact independent aspects of scientific endeavour. The recognition that scientists have no a priori knowledge - that all data is to some extent infused with theory however, speaks against the autonomy of theory and evidence in scientific research (T.S. Kuhn, 1970; Hooker, 1987).

In order to reason in a scientific manner, Deanna Kuhn requires that her subjects not only differentiate theory and evidence, but also co-ordinate the two in the appropriate manner. For Kuhn, this amounts to accepting theories as confirmed by supporting evidence, and rejecting theories as invalid in the face of contradictory data. These requirements would seem to rest squarely on the idea underwriting the hypothetico-deductive method (hereafter HD method) that testing theories for their predictive accuracy is a decisive test of a theory's worth. Such an assumption however has been overturned by the recognition embodied in what has become known as the Duhem-Quine thesis, that theories are notoriously underdetermined by empiricial evidence.

Related evidence against the claimed disparity between lay people and scientists, is to be found in analyses of how scientists do in fact view the relationship between theory and evidence. Despite Deanna Kuhn's claims to the contrary, scientists in general seem decidedly unwilling to relinquish their theories whose empirical predictions are not borne out by the data. Instead they will often tenaciously hold on to their theories in situations where, on a strict logical model of inquiry, one would expect the theories in question to be refuted (T.S. Kuhn, 1970; Lakatos, 1970; Feyerabend, 1975).

From the points listed above, hypothetico-deductivism seems at the very least rather precariously placed as an adequate theory of scientific method. Its adequacy is further jeopardised when one considers how little of the process of knowledge development in science HD method actually covers. For example, because on this account a theory is taken on board as a fixed and finished entity 'ripe for the testing', there is a disconcerting lack of attention given to theory generation and development. As indicated earlier, HD method takes science to properly begin with the validation of theories via empirical test. The discovery process that precedes this point is dismissed as beyond rational characterisation (on a logical model of rationality), and therefore open only to a psychological interpretation (Giere, 1988). However by dismissing this context from sight as nonscientific, HD method fails to realise that there are patterns of reasoning governing theory creation that are indicative of a logic to discovery (Haig, 1987).

HD method not only falls short by locating the 'beginning' of scientific inquiry within the context of justification, it also fails to provide an adequate treatment of this context, by demonstrating an exclusive concern with empirical adequacy. The underdetermination of a theory by empirical evidence however, means that any evaluation process based solely on this criterion is clearly incomplete. Recognition of this fact has led philosophers to search further afield for criteria by which to judge a theory's worth. Candidates recommending themselves for inclusion in a broadened account of the justification of scientific theories include consilience, simplicity, explanatory depth, fertility, and practical utility (T.S. Kuhn, 1970; McMullin, 1983; Thagard, 1988).

In sum, this section has attempted to highlight some of the inadequacies of the received view of science that underlies much of the child-as-scientist literature. In looking for an appropriate account of science to act as a standard for assessing children's thought, a fundamental requirement is that it demonstrate the capacity to capture the reality of scientific practice. From the criticisms outlined above, empiricism would seem woefully inadequate in this regard. It is time then to consider an alternative.

1.3 Evolutionary Naturalistic Realism : an alternative framework

"Empiricists aim to base knowledge on facts and confine knowledge to the facts".

Hooker, 1985

"Science is concerned with creative cognitive construction in the face of evolutionary ignorance".

Hooker, 1987

As argued at the beginning of this chapter, in considering the utility of the child-as-scientist analogy, a necessary preliminary is to ensure that the model of rationality projected from science to commonsense, is an adequate one. The indications that the empiricist standard currently underlying much of the child-as-scientist literature does not meet this basic demand, requires that attention be directed towards an appropriate philosophical alternative. Such an alternative it is suggested, is to be found in the school of philosophical thought known as "Scientific Realism".

Scientific realists broadly speaking, hold the view that there is a real world that exists independently of our cognitions about it, and that our most valuable theories are our best guides to the nature of that reality. Beyond these baseline assumptions however, a variety of realist stances present themselves for consideration. Far from being a uniform philosophical position, advocates of scientific realism express a plurality of views on such matters as the actual achievements of the scientific enterprise, the correct interpretation of intertheory relations, the referential status of theoretical terms, and the notion of truth and its role in cognitive activity. Of these multiple forms, a particular brand of realism defended by Hooker (1987) stands out as the most penetrating philosophical account of the nature of the scientific enterprise. It is to this theory of science entitled "Evolutionary Naturalistic Realism" (ENR), that attention is now turned.

Hooker begins his defence of ENR by linking the adequacy of a theory of science to our evolutionary circumstances. For creatures born in ignorance he asks, what is a rational strategy to adopt for advancing knowledge? The empiricist programme of limiting scientific inquiry to the observable realm has traditionally been deemed rational in light of its avoidance of *epistemic risk*. Indeed the trademarks of empiricist science, namely the focus on observables, the limitation of theories to harmless ordering instruments, and the confining of scientific reasoning to formal logics, can all be conceived as strategies of *risk reduction*, the presumed reward for implementing such a policy of caution being the promise of certain or near certain knowledge[2].

Aiming to base knowledge on facts and deploying cautionary strategies to ensure that knowledge is confined to the facts however, is only a rational policy if the certainty of existence promised by the observable realm, is not an illusion. Revelations that observability is anything but a safe guide to existence, that there is no level of indubitability, no theory-neutral foundation for knowledge (Hooker, 1985; Churchland, 1985), leaves the empiricist programme up in the air - its credibility as a risk-containing (and hence rational) enterprise hanging on an idiosyncratic distinction between what is and is not currently observable.

By attempting to minimise epistemic risk in this way, the empiricist programme in fact runs the far greater risk of seriously retarding the advance of knowledge. Because much of the 'causal architecture' of the world is hidden from our gaze, it is plausible to assume that science requires strategies that enable inquirers to go below surface appearances in order to reach the deep seated causal mechanisms that purportedly underlie and give rise to phenomena (Hooker, 1985). The cautionary measures undertaken by empiricism however, mean that the resulting focus on the observable realm will produce knowledge claims that at best will be seriously lacking in explanatory depth. Considering our evolutionary circumstances as "creatures exploring the world from an original position of ignorance" (Hooker, 1985, p.179), the adoption of such a programme for science would seem decidedly *irrational.*

In contrast to empiricism's maxim to avoid epistemic risk at all costs, the realist alternative advocated by Hooker (1987) attempts to take stock of our situation in the world and design a realistic strategy for advancing knowledge that accords with a view of ourselves as products of biological and social evolution. Starting from a position of ignorance, Hooker argues that we have no choice but to accept risk as an unavoidable part of the knowledge development process. Because

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[2] The minimization of risk can also be seen as the motivating force behind neo-empiricists' attitudes to theory acceptance. van Fraassen (1980) for example, advocates the view that the acceptance of a theory is properly a commitment only to empirical adequacy, *not* truth.

there is no independent access to the world, all our knowledge of what exists in the world must necessarily come to us via our theorising efforts. The knowledge claims that result from such efforts will inevitably be fallible since they are the products of human cognizers. Hence knowledge on ENR is best viewed as "warranted conjectural theory" (Hooker, 1987).

In articulating his view of science, Hooker embraces a strong 'aim oriented' conception of rationality, according to which scientific inquiry is interpreted as properly concerned with the pursuit of *valuable* knowledge. According to Hooker, valuable knowledge is knowledge that will enable us to solve our most pressing problems of existence. Science on ENR (unlike traditional accounts of realism), is not construed in isolation from the human individual and from society. Rather it is seen to be a collective human endeavour, aimed at reducing the poverty of our ignorance, through the utilisation of our evolved cognitive resources for theorising within complex social structures (institutions) designed to promote collaborative inquiry. On Hooker's realist philosophy, science is very much a *species strategy*, the rationality of which derives from its service to humankind as a powerful system for ensuring our collective survival.

On such a radical reinterpretation of science, the characterisations of theories and scientific methods can be seen to differ markedly from those given on an empiricist account.

1.3.1 Realist theories

ENR claims that all knowledge is theoretical knowledge, and hence it is our best extant theories that are our most reliable indicators of the nature of reality. In sharp contrast to empiricism's 'fact-file' characterisation of theories as convenient structures for organising objective observations, realist theories are construed primarily as *explanatory tools,* constructed by human cognizers in an effort to obtain a 'representational handle' on the world. In Hooker's terms, theories move from being merely dispensable empiricist "instruments of convenience" with no truth-value status, to their central realist role as "proponents of risk-taking endeavour" (Hooker, 1987). On a realist construal of science, theories represent our species' epistemological ticket out of ignorance.

In order to function effectively in this role, theories will necessarily be deep-structural or postulational in character, foregoing a concern with description of observables in an effort to construct a (plausible) causal story of the entities thought to underlie and explain such phenomena. Not only do realist theories optimally function at some depth below the empirical surface, but their preferred scope will be wide. Whereas empiricism's concern has traditionally been with small-scale (often singular) knowledge claims seen to operate independently of the rest of science, Hooker (1975) places great import on the role of *global* theories in science, citing their integrative and unifying powers as a major scientific virtue in the pursuit of holistic understanding.

Theories on ENR are further viewed as dynamically evolving entities which are inadequately captured by the static structural characterisations they are given on an empiricist account. From an evolutionary naturalistic realist perspective, scientists are seen to advance knowledge by generating a plurality of theoretical alternatives, which are then developed through a multi-criterial process of critical comparative evaluation (Haig, 1995).

1.3.2 Realist methods

For creatures evolving from ignorance, method is of primary importance since as Hooker points out, " . . . method is all that we have" (1987, p.41). Discarding the empiricist conception of knowledge as fact, for a fallibilist view of knowledge as warranted conjecture, necessitates that serious attention be directed towards our knowledge-making methods. In doing so, realists are led to reject the received view of scientific method as a logical algorithm for extracting truth. As Hooker makes clear, once we reflect on our evolutionary circumstances, we realise that not only do we possess no a priori knowledge, but we also are without a norm-free methodology. Instead our methods are seen to evolve in interaction with our theories, with our accepted theories of the world determining which methods are most appropriate for us to adopt, and our best methods providing the justificational warrant for our theoretical conjectures (Hooker, 1987).

Far from factoring the human component out of the knowledge production process (as witnessed in empiricism's attempts to restrict science to the facts and logic), ENR looks to capitalise on the natural reasoning capabilities we have evolved for making sense of phenomena. Accordingly, on a realist account of science the generation of knowledge is seen to occur through an abductive inferential process, whereby scientists make informed guesses about an independent reality by reasoning from the phenomena in question to reach an explanation of the causes underlying the phenomena (Haig, 1995).

In giving serious attention to the aim of relieving our ignorance, ENR looks to an account of scientific method that will promote the development of substantive theory. While the received view typically limits itself to a concern with scoring knowledge claims on empirical adequacy tests, and hence is ill-designed to achieve this end, an adequate realist account looks to provide scientists with a systematic approach to theory-building which is concerned with the full developmental history of a theory. Accordingly, such an account will be wholistic in character instead of focusing solely on theory testing, and will embrace the process of knowledge construction in its entirety, giving explicit attention to the multiple contexts of theory generation, theory development, and theory appraisal (Haig, 1987).

The outline given above has provided only a brief characterisation of ENR (a more detailed presentation of a realist perspective on scientific method will be undertaken in Chapter 4 in line with its role as a standard for children's problem solving), however it would seem sufficient to recommend this realist account of science as an appropriate framework for investigating the child-as-scientist analogy on at least three counts:

1) It is normatively adequate in that it embraces the recognition that we need to match our theory of how science should be practiced to our circumstances in the world.

2) It gives serious attention to actual science and hence has the capacity to genuinely illuminate the reality of scientific practice.

3) On this philosophical account, science is not viewed as a fundamentally different sort of endeavour to everyday intelligent reasoning (as empiricism would have it). Rather scientific discovery is conceived as a human activity - a refined outgrowth or extension of our commonsense attempts to make sense of the world.

This study then can be seen to constitute an investigation of the child-as-scientist metaphor, with 'science' understood in realist terms. Armed with this framework the stage is set for developing informative parallels between science and commonsense.

2

The nature of folk psychology

In the previous chapter it was proposed that any plausible argument for the child-as-scientist model, necessarily begins in an assessment of the nature of theories and scientific reasoning. Accordingly, a realist account was endorsed as the most adequate characterisation of scientific thought, and hence the most appropriate framework for examining the relationship between science and commonsense. With a scientific framework in place therefore, this chapter turns its attention to everyday cognition, more specifically our commonsense understanding of human action or *folk psychology.*

In looking to establish that theoretical knowledge is common to both scientists and children, folk psychology with its rich conceptual apparatus for comprehending human action, presents itself as a likely candidate for an everyday theory. As one of the first commonsense frameworks to emerge in humans, it has also attracted much attention from developmentalists wishing to argue that cognitive development be viewed in terms of theory construction. However, to perceive the child's acquisition of folk psychology as the development of a theory, necessitates that the underlying structure of our commonsense psychological understanding is in fact theoretical. Is it really plausible to suggest that folk psychology constitutes a genuine empirical theory?

Researchers objecting to the 'theoretical view' (Morton, 1980; Wilkes, 1984), have claimed that folk psychology cannot be considered a theoretical structure because it does not consist of laws and does not support causal explanations, and its primary function is not that of an explanatory theory. In short , these critics suggest that folk psychology does not function in the way that theories do. Further criticisms focus on the distinctive nature of folk psychology. Researchers such as Harris (1989), Gordon (1992), and Goldman (1993), argue that the manner in which we understand ourselves and our conspecifics is fundamentally different from understanding in other domains. In their view, our everyday psychological understandings arise from a process of "simulation" and are not the result of applying any theory, tacitly or otherwise.

We have here, then, two bodies of criticism against the theoretical view. One compares folk psychology to a certain conception of scientific theories and finds it wanting; the other attaches a special status to our mentalistic construal of human action, and in doing so distinguishes it from theoretical knowledge. Tackling both forms of objection constitutes the work of this chapter. It will be argued that a consideration of these criticisms, together with an investigation of an alternative account of our understanding of human behaviour, lends credence to the view that folk psychology *is* theoretical in nature.

2.1 Folk psychology as theoretical knowledge

A primary objection to folk psychology's proposed theoretical status, concerns the generalisations that it employs. To take one example, Morton (1980) has indicated that this "stock of beliefs" cannot be seen to constitute a theory, because its generalisations do not have the character of genuine causal-explanatory laws, and therefore do not function in the manner required. Instead Morton argues for a somewhat 'looser' characterisation of folk psychology, something he terms a "scheme". On this account our folk psychological explanations do not derive their authority from any fixed body of empirical principles or laws; there is no fixed content, only a set of underlying implicit constraints. However, as Churchland (1984) makes clear, a rich network of commonsense laws *can* be reconstructed from our everyday commerce, which (despite Morton's claims) do function in the appropriate manner. As with other theories, the laws of folk psychology depict the relations holding between the various entities postulated by the theory, these laws give meaning to the theoretical terms they contain, and they are more than normative principles or rules, in that they carry out causal-explanatory work (Churchland, 1991). Furthermore, rather than comprising a collection of disparate laws, Churchland persuasively argues that folk psychology is essentially a theoretical network or framework, that postulates a range of internal states whose causal relations are described by the theory's laws, and as such, does indeed support causal explanations.

It is likely that Morton's particular objections to the 'theory theory', stem from the particular characterisation of scientific theories utilised in his anti-theory claims. In Chapter One, it will be remembered, meaningful comparisons between folk psychology and theoretical structures in science were seen to operate at the level of framework theories. However, in looking to criticise the theoretical view, Morton seems concerned with more specific theoretical structures in science.[3] Indeed in his proposed *'alternative'* to the theory theory, Morton appears to be trying to account for the very features of folk psychology that are suggestive of its framework-theoretical status. That Morton's so called 'scheme' closely resembles a framework theory can be seen by the examples he gives to illustrate his proposal, namely composing within a musical tradition, giving a legal judgement in accordance with a body of precedents, and speaking a dialect of a language. The common theme amongst these examples is that they all evidence a similar structure. That is, they all seem to be getting at the idea of a framing body of knowledge within which there is improvisation and variation in the specifics, these variations however being ultimately constrained by the parent framework under which they are housed. Yet if this estimation of Morton's 'scheme alternative' is correct, then stated as such it fails to present a convincing challenge to the theory argument endorsed in this thesis, since it does not differentiate itself sufficiently from the claim that similarities exist between commonsense psychology and framework theoretical structures in science.

A further objection to the theoretical view highlights the variety of uses beyond explanation and prediction for which folk psychology is employed. Wilkes (1984) makes the point that folk psychology's resources are utilised for a score of social functions, which she proposes fall outside the realm of those functions rightly ascribed to theories. While Wilkes does not deny that the apparatus of folk psychology is used to explain and predict, she thinks the importance of such functions are greatly diminished when one considers the countless other tasks in which our folk psychological framework is routinely engaged, for example blaming, consoling, insinuating, congratulating, rebuking, to name but a few. Viewed in this light, folk psychology is very much a "multi-purpose tool" and as such says Wilkes, is to be sharply contrasted with scientific theories which are solely in the business of description and explanation. The implication is clear. Folk psychology would have to be stripped of all its 'extra-curricular' social roles in order to fit the mould of a scientific theory. As it stands, folk psychology is best conceived as a vehicle for social commerce, rather than an explanatory theory.

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[3] That is, he seems concerned with theories that can be explicitly stated and hence subjected to the rigours of empirical testing.

There are two related points to be made here. Firstly, the fact that our commonsense psychology boasts a multitude of purposes, should not dissuade us from labelling it a theory. From a realist perspective on science which takes science to be a multi-purpose endeavour, there is no inconsistency in allowing that a scientific theory be multi-functional. To illustrate, Graham (1990) in a consideration of the genesis of our folk psychological framework, endorses both its theoreticity and its role in matters of social commerce. In essence, he views folk psychology as a "theoretical tool" that became part of our conceptual equipment because it enabled us to explain and predict behaviour, and hence provided its bearers with an adaptive advantage in social situations. Contra Wilkes, the social usefulness of our folk psychological framework in no way negates its theoretical status. Rather as exemplified by Graham (1990), the two go hand in hand.

The recognition that social usefulness and explanatory and predictive capacities are closely intertwined, prefigures the second point to be made here, namely that it is not at all obvious that the social functions Wilkes highlights *should* fall outside the list of those functions correctly ascribed to theories. Graham's work is instructive, because it makes clear that in discussing the social functions folk psychology performs, we are really discussing folk psychology's practical utility in its domain of operation. By divorcing folk psychology's role in social commerce from those roles rightly ascribed to theories, Wilkes is in fact divorcing theoreticity from practical usefulness. As such, her argument against the theory-theory can be seen to rest on a decidedly narrow interpretation of the nature of theories and their function, since it essentially amounts to a rejection of folk psychology's theoretical status on the basis of its practical application in the world. Paul Churchland makes the point thus:

". . . theories are the conceptual vehicles with which we literally come to grips with the world. The fact that folk psychology serves a wealth of practical purposes is no evidence of its being non-theoretical. Quite the reverse." (1991, p. 43).

Morton (1980) also points to the functions of theoretical structures in his bid to demonstrate that folk psychology is not a theory at all, but rather something less empirical, namely a "scheme". And like Wilkes, his argument can also be seen to rest on a narrow rendering of theory:

" . . . theory is risky. It depends on a delicate balance of conjecture and fact, imagination and prudence . . . Free imaginative hypotheses are allowable in science just because they take place within a network of tests, observations, and opportunities for critical reflection, that ensure public criticism of hypotheses and give refuting considerations a chance to appear" (1980, p. 29).

Morton's underlying philosophy for such an argument, in a similar manner to other critics of the theory view discussed in Chapter One, would appear to incorporate a strong demarcation of science and non-science, where theorizing is properly seen to be a scientific process, and where folk psychology falls down because it lacks the necessary scientific balances and controls. In contrast, this work drawing on a realist philosophy of science endorses the view held by Karmiloff-Smith (1988) and Gopnik (1990) that both scientists and lay people are knowers, and that theory-building is a natural human tendency which both groups utilise in attempts to achieve order in their world. Given this view, to argue that folk psychology does not attain the status of 'theoryhood' because it does not embody scientific balances and controls or because it works for us in the world, would seem implausible. Rather, it is suggested that our commonsense psychological understanding is properly viewed as a 'proto-science' - an early developing account of persons, whose status as an empirical theory is justified by its ability to explain and predict human action. As Churchland (1991) points out, in our everyday endeavours we standardly employ folk psychology to carry out causal-explanatory work. That is, we postulate that people act in accordance with their beliefs and desires in order to anticipate and gain some understanding of the actions of those around us. Indeed as Fodor (1987) has emphasised, the folk psychological assumption that our behaviour is 'thought-directed' - specifically that our actions are caused by our beliefs and desires in complex interactions with one another, serves us remarkably well in everyday contexts.

Those rejecting folk psychology's proposed theoretical status do not deny that we use our body of folk psychological beliefs to explain and predict, and even acknowledge our large measure of success in these endeavours, but continue to maintain that folk psychology is not properly conceived as a theory. The suggestion made here is that these objectors miss the point that it is precisely these explanatory and predictive successes that indicate we are in possession of a theoretical structure. As Churchland points out, to be able to:

a) recognise one's own actions as resulting from an interplay between one's beliefs, desires, and intentions regarding the world, and,

b) extrapolate from oneself to anticipate and manipulate the actions of other people,

is already to be in possession of a conceptual understanding of mental phenomena, of their general connections both with each other and with behaviour (Churchland, 1991). Such a framework whether in a commonsense or scientific domain, is literally a theory.

2.1.1 Folk psychology and the eliminativist challenge

If it can be accepted from the proposals outlined above that folk psychology constitutes a theory, then we are immediately faced with yet another challenge to our commonsense framework, this time concerning its integrity. The argument, voiced most notably by Paul and Patricia Churchland takes the following form:

Folk psychology is an empirical theory; as such we should evaluate it in the same manner that we evaluate theories in science.

In the process of such an evaluation we discover that folk psychology stands up poorly to concerted theory appraisal - it is revealed as a false theory that grossly misrepresents the causes of human behaviour.

Therefore it should be rejected and replaced by a superior alternative, namely a completed neuroscience.

Hence the Churchlands' call is for outright elimination of folk psychology.

If correct, the Churchlands' argument strikes a blow against the programme of this thesis, which seeks to develop the relationship between science and commonsense, since questions raised concerning the integrity of folk psychology will by implication impact on the validity of lay cognition more generally. Clearly, if young children are constructing and utilising a conceptual framework that approximates none of the regularities actually existing in the world, then the force of the claim that the child be seen as an intuitive scientist, is greatly diminished. There is a need, then, to defend folk psychology from calls that it be placed under the eliminativist's knife. An outline for such a defence can begin to be constructed on two fronts.

The first concerns the impact that an advancing neuroscience is forecast to have on the integrity of folk psychology. In evaluating folk psychology, Paul Churchland (1981) argues that our folk theory demonstrates manifest failures, the most critical of these being its lack of coherence with our best theories in adjoining fields, in particular that of neuroscience. Indeed, Churchland's eliminative claims can be seen to stem predominantly from his consideration of the notion of incommensurability as promoted by Kuhn (1970) and Feyerabend (1962), according to which the irreconcilibility of two theories in science results in the abandonment of the older theory for its superior successor. However, as a number of writers have noted (Horgan & Woodward, 1985; Greenwood, 1992), Churchland's allegations against folk psychology can be seen to rest on an implausibly strict reductive criterion, such that folk psychology must be *reducible* to a lower level theory in order to cohere with it. As Sterelny (1991) makes clear, in arguing his case for the theoretical isolation of folk psychology from the accepted body of scientific knowledge about the mind, Churchland fails to adequately distinguish between physical *realisability* and *reducibility.* Demonstrating the coherence of folk psychology with the view of ourselves as complex physical systems, requires only that our commonsense psychological theory demonstrate the former, not necessarily the latter (Sterelny, 1991).

A related problem with Paul Churchland's 'incommensurability hence elimination' argument, is that it rests on an inadequate model of intertheoretic relations. A more satisfactory model (see McCauley, 1984) that distinguishes the relations that hold between successive theories at a certain level of analysis over time, from those that hold between theories at varying levels of analysis at the same time, reveals that the replacement of theories (as witnessed in the history of science) is an *intra-level* phenomenon. The mistake Churchland makes is that his eliminative conclusions regarding the inter-level theoretic relations holding between folk psychology and neuroscience are based on an analysis appropriate to intra-level contexts (such as the relation holding between folk psychology and cognitive psychology). Put simply, where folk psychology is concerned, neuroscience would have to be in the position currently occupied by cognitive psychology in order to 'catch a piece of the (eliminative) action'.[4]

A similar conclusion regarding the deficiencies in Paul Churchland's eliminative argument is reached if one focuses on the notion of theoretical pluralism. Clearly, Churchland's motivation to critique folk psychology and to adopt neuroscience as a superior alternative is in line with his commitment to

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[4] I would want to add to McCauley's model of intertheoretic relations a consideration of *context.* That is, the basis for both his and Churchland's comments is intertheoretic relations in the history of science. In the case of folk psychology and neuroscience however, we are concerned with theories that not only operate at different levels of description but also in differents contexts - everyday and scientific. One would expect the resulting intertheoretic relations to differ from those existing between two theories utilised in science. Such an expectation seems to be borne out by Chi's (1992) findings concerning intuitive physics. Following formal education in physical science, the scientific theory does not appear to either reduce or replace the commonsense theory, rather the two tend to coexist.

theoretical pluralism, part of which involves the view that theory appraisal must be comparative. However, what is not clear from Churchland's endorsement of neuroscience at the expense of folk psychology, is that theoretical pluralism operates in two distinct senses, and in only one of these is comparative theoretical evaluation appropriate.

Whereas in discussing theoretical pluralism *within* levels we are dealing with theories that are properly seen to be competing theoretical alternatives, when we turn to consider theoretical pluralism *between* levels it is not at all obvious that the different theories should be viewed as competing. Not only do they employ different concepts and principles which serve to highlight different aspects of the object of study (in this case the mind/brain), but as a result they also offer accounts that are more or less effective with different problems. Here it makes much less sense to carry out comparative analyses across levels and argue for the superiority of one theory over others. Yet in his calls to eliminate folk psychology and replace it with a superior neuroscientific alternative, it would seem this is exactly what Paul Churchland is proposing.

The second front on which to challenge Churchland's argument, concerns his claims that folk psychology is a degenerating research programme. To propose that folk psychology demonstrates explanatory impotence and is essentially nonprogressive, is to give our commonsense theory a bad review. Folk psychology works very well in everyday contexts precisely because it embodies a measure of explanatory and predictive power.[5] Granted this power is not the result of any microreductive analysis (perhaps the Churchlands as ardent physicalists would not be so harsh in their judgements if it was), but then as indicated above, it is questionable whether a microreductive neurophysiological account would provide the theoretical illumination required in everyday contexts. Nor is it true to say that folk psychology has not progressed at all. One needs only to consider our current views of psychopathology and compare them with earlier notions of demonic possession to see that conceptual development has taken place.

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[5] One plausible way in which to argue for this claim, is to view beliefs and desires as <u>dispositions</u>, which are invoked to provide dispositional explanations of the behaviour to which they give rise. On a realist view, dispositions can be seen to have genuine explanatory power. Specifically with regard to beliefs and desires, this explanatory power involves two aspects:
a) <u>explanatory depth</u> - beliefs and desires are successful at extending our referential reach
b) <u>explanatory breadth</u> - they offer us some measure of consilience in our everyday attempts to understand human action, by 'binding together' their variable displays. (For a comprehensive treatment of the view that dispositions do explain, see Rozeboom, 1984).

In sum, claims for the integrity of our folk psychological framework, and hence its retention in everyday contexts, are not the result of complacency, despite the Churchlands' attempts to paint supporters of folk psychology in this light. Rather folk psychology's staying power derives from its unsurpassed usefulness in our everyday attempts to explain, predict, and manipulate the actions of those around us. Contrary to the Churchlands' claims that folk psychology is ripe for elimination, our commonsense theory has not outlived its adaptive utility; the most likely reason being that it is at least partially successful in capturing some of the regularities existing in the world. The eliminative claims presented here at least provide no reason to reject such a conclusion.

2.2 The nature of psychological knowledge

A quite different challenge to the theory theory, is articulated in the form of an alternative account of our psychological knowledge. Rather than comparing folk psychology to a particular model of scientific theories and declaring it inconsistent, or challenging its integrity as a valid theoretical framework for understanding one another, this alternative conception questions whether we really *need* a theory to make sense of human action. According to philosophers such as Gordon (1986) and Alvin Goldman (1989), our understanding of one another does not stem primarily from a system of nomically embedded concepts. Instead, we explain and predict each others' actions by drawing on the resources of our own minds to *simulate* the 'workings' of others. In short, in the case of our everyday psychological understanding we are simulators rather than theorists.

At first glance, simulation theory presents itself as a far simpler explanation of how we typically arrive at judgements about the mental attitudes of others, since it deems an elaborate system of internally represented generalisations or rules, unnecessary. Gordon voices such a belief thus:

"Insofar as the store of causal generalisations posited by (the theory theory) mirrors the set of rules our own thinking typically conforms to, the Simulation Theory renders it altogether otiose. For whatever rules our own thinking typically conforms to, our thinking continues to conform to them within the context of simulation . . . In the light of this far simpler alternative, the hypothesis that people must be endowed with a special stock of laws corresponding to rules of logic and reasoning is unmotivated and unparsimonious" (Gordon unpublished, cited in Stich and Nichols, 1992, p.52).

On such an account, simulation seemingly avoids the need for a theory of mind, simply by taking advantage of the presumed structure of the mind itself. Hence according to Gordon, simulation theory is in direct competition with a theoretical account of our understanding of human action.

Does simulation in fact render a theory of mind redundant? Any attempt to provide an accurate answer to this question necessarily involves a comparative evaluation of the two theoretical explanations along a number of dimensions. It would seem important to ask firstly, whether an understanding of mind is different in essential respects from understanding in other domains. For example, is the process underlying our understanding in the psychological domain quite different from the process by which we come to understand other phenomena? Secondly, and in connection with such questions, one would need to consider what provides the *foundation* for our knowledge of human action. While our capacity for mental simulation may well be drawn upon in the process of acquiring such knowledge, it is far from clear whether simulation in the absence of a theory has the capacity to provide a sufficient base for such knowledge.

2.2.1 Understanding others: just what sort of knowledge is involved?

In the previous section, arguments were detailed in defence of the proposal that folk psychology is a theoretical structure, hence implying that our knowledge of human action is generated in the same way as our knowledge of the rest of the world, that is, by a process of theory construction. For some however, such a claim ignores arguably the most significant feature of the domain in question, namely the recognition that as persons we are endowed with similar cognitive structures and share a wide range of experiences with those we attempt to understand. As Harris (1989) points out, in making judgements about and attributing mental attitudes to other people, we are invoking mental states that we ourselves experience every waking day. Therefore, it appears reasonable to speculate that in attempting to understand our conspecifics, we have the opportunity to engage in some sort of 'projection' from our own case to that of others. Hence it would seem strange, say those in favour of simulation theory, that instead of putting this 'advantage' to good use, we opt for a fundamentally *nonprojective* basis for explanation and prediction, namely a theoretical framework.

A primary concern in assessing the plausibility of such a proposal is to determine just what exactly this 'advantage' alluded to above, entails. On this point, advocates of simulation theory differ. Harris' (1992) version of simulation, seems to suggest that the 'advantage' we possess in the domain of psychological knowledge is privileged access to our own mental states. Indeed he claims that "privileged access is an important feature of our mental lives" (p.141), and one that has the potential to embarrass those adherents to the theory theory who have ignored the role of such access in our understanding of human action. However, despite the fact that his account of simulation rests on an appeal to privileged access, Harris fails to undertake any consideration of how we come to have immediate and privileged knowledge of our sensations, emotions, beliefs, and desires. For example, it would seem important to ask why from an evolutionary perspective, the mind should be transparent to itself? As Paul Churchland (1984) points out, the view that the mind knows itself first, in a unique way, and much better than it can ever know the external world, does not cohere with the recognition that what individuals know first and best must surely be the environment in which they have to survive. Moreover, Harris' anti-theory account rests on the supposition that 'self perception' has developed in such a way that it is fundamentally different from our perception of the external world, yet the grounds for maintaining such a proposal, remain unclear.

In light of such questions, the proposal that the 'advantage' we possess in the psychological domain takes the form of some mysterious Cartesian self-awareness, would seem in the very least, rather implausible. The implausibility of such an account however, is perhaps most telling if one considers the course of development in childhood. Gopnik & Wellman (1992) present empirical data on children's errors and inaccuracies in attributing mental states to themselves and others, which are inconsistent with the position that children have privileged access to their own mental states. Specifically, these researchers found that such errors and accuracies did *not* differ between self and other in any clear fashion, but rather divided between certain theoretical constructs differing in complexity, such as beliefs and desires.

Gordon (1986, 1992), in contrast to Harris, rejects any appeal to Cartesian doctrine in his version of simulation theory. He maintains that the psychological process by which we acquire knowledge of human action is very different from the process by which we acquire knowledge in other domains, but claims this is not the result of any privileged access. Rather, he argues that the fact that we are endowed with the same cognitive systems as those we attempt to understand, means that such understanding can be achieved by a process of simulation; that is, by "using our imagination to identify with others in order to explain or predict their behaviour" (Gordon, 1992, p.87)[6] . Such an account seems to rest on the following perception of how our cognitive system normally functions:

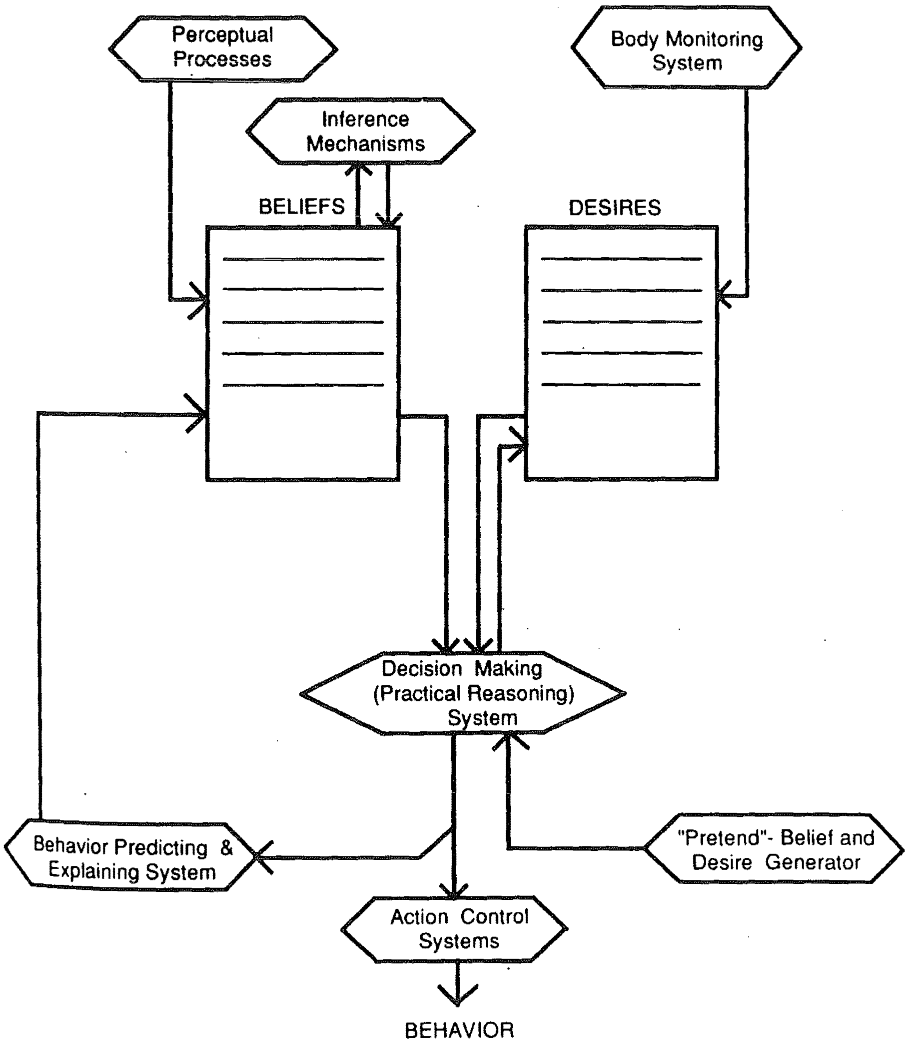

Figure 1

Diagram of functioning cognitive system (from Stich & Nichols, 1992 p.40)

To take our capacity for prediction of others as an example, Gordon (1986) provides this account of the simulation process:

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[6] This argument does depend heavily on Gordon's assumption that our cognitive systems *are* in fact the same and not merely similar. If they were only similar then intuitively the simulation account given above would seem insufficient to account for our ability to understand the behaviour of others.

" . . . our decision-making or practical reasoning system gets partially disengaged from its 'natural' inputs and fed instead with suppositions and images (or their 'subpersonal' or 'subdoxastic' counterparts). Given these artificial pretend inputs the system then 'makes up its mind' what to do. Since the system is being run off-line, as it were, disengaged also from its natural output systems [ie: action control systems], its 'decision' isn't actually executed but rather ends up as an anticipation . . . of the other's behaviour" (1986, p.170).

According to such an account, mental simulation involves the capacity for practical reasoning together with the ability to incorporate 'pretend' facts and values into the system in order to make adjustments for relevant differences between self and other. In order to predict someone's actions, then, rather than deploy a theory, we simply use part of our own cognitive mechanism to simulate the workings of part of theirs. A similar idea appears to be involved in Goldman's (1989) proposal that simulation can be *"process-driven":*

"This can happen if (1) the *process* that drives the simulation is the same as (or relevantly similar to) the process that drives the system, and (2) the initial states of the simulating agent are the same as, or relevantly similar to, those of the target system. Thus, if one person simulates a sequence of mental states of another, they will wind up in the same (or isomorphic) final states as long as (a) they began in the same (or isomorphic) initial states, and (b) both sequences were driven by the same cognitive process or routine. It is not necessary that the simulating agent have a theory of what the routine is, or how it works" (p.173).

A further point made by Gordon in defence of simulation theory, is that the capacity for simulation may be largely innate. Pointing to the human tendency to mimic other people's bodily postures, especially facial expressions, and to the tendency found in many mammals of turning their eyes toward the target of another's gaze, Gordon argues that the "readiness for practical simulation is a prepackaged 'module' called upon automatically in the perception of other human beings" (1986, p.170).

In contrast to invoking some mysterious Cartesian self awareness, Gordon's account of how simulation might operate is far more appealing. Intuitively, the existence of such a module makes good sense. Any mechanism that gave one the ability to interpret and anticipate another's actions, would certainly provide a decided advantage to the bearer. The plausibility of an innate capacity for simulation however, provides *no* reason for rejecting a theoretical account of our psychological understanding, despite appeals to the contrary. While it is true that the theory theory traditionally articulated makes no allowance for mental simulation[7], there is no reason why it should deny that simulation is involved in the process of understanding. As Paul Churchland (1991) points out, it is reasonable to assume that a great portion of our appreciation of human action does derive from our ability to examine and extrapolate from our own case. But this is hardly inconsistent with a theoretical account of our understanding of human behaviour, nor does it render such an account redundant, since - "[one] learns from every example of humanity one encounters, and one encounters oneself on a systematic basis" (Paul Churchland, 1991, p.45).

Indeed, the main achievement of those advocating simulation theory would seem to be the clarification they have given to the concept of mental simulation and to how it might operate in our ascription of mental attitudes to others. What proponents of simulation theory have not achieved, I maintain, are grounds to reject the basic tenets of the theoretical view. For such a rejection to be warranted, it would be necessary to demonstrate not merely that mental simulation has a part to play, but that simulation (devoid of any underlying theory) is the foundation for our psychological knowledge. And it would seem that such a position has yet to be convincingly put forward by any defender of simulation theory.

2.2.2 Simulation: the foundation of interpretation?

A primary objection to the view that simulation is the originating source of psychological interpretation, is that simulation is not *necessary* for understanding the behaviour of others. To take an example, Johnson (1988) in the following passage echoes a view held by many advocates of simulation theory:

"Simulation avoids the need of a theory of mind . . . It allows children to make efficient and adaptive use of their own conscious experience to understand the experience of others" (p.58).

But if this was the case then our experience would necessarily define the limits of our understanding of human action (Paul Churchland, 1991). Landau & Gleitman (1985) provide data which contradict Johnson's claim, clearly indicating that our psychological knowledge is not so limited. In their

[7] For some researchers, it is this 'deletion' that would seem to be the primary motivation for advocating the plausibility of mental simulation (see Goldman 1989, 1992).

experimental and observational work, these researchers detail how congenitally blind children are able to learn about words such as "look" and "see" whose meanings would appear to depend fundamentally upon sight. Far from being "empty verbalisms", blind children aged 3-4 years were found to attribute such "sighted vocabulary" to others and not to themselves. Furthermore, Kelli a young blind child involved in the research, clearly displayed knowledge of the distinction between the terms "look" and "see" as they apply to sighted people - she knew that there were occasions on which her mother "looked" but did not "see". How such knowledge is acquired, would seem to be an anomaly on a simulation account. Clearly it is not acquired via simulation of first person experience. But if first person experience is not necessary for understanding the behaviour of others, then it can hardly be heralded as the foundation for such knowledge.

Another problem with the simulation theory, standardly conceived, is alluded to by Dennett (1987) who questions how it can work without being a kind of theorizing:

"If I make believe I am a suspension bridge and wonder what I will do when the wind blows, what comes to mind depends on how sophisticated my *knowledge* is of the physics and engineering of suspension bridges. Why should making believe that I have your beliefs be any different? In both cases, knowledge of the imitated object is needed to drive the make-believe 'simulation', and the knowledge must be organized into something rather like a theory" (p.100).

There are a number of points to be made here. Firstly, it would seem that in projecting mental states onto another person, one generally has to make 'imaginative adjustments' in one's states to account for differences in situation. And making such adjustments, rests on the ability to discriminate one's mental states. But surely this requires that one is already in possession of the relevant *concepts,* which in short would presuppose a theory. Gordon (1992) objects to the conclusion that one could not simulate a type of mental state unless one already had the concept of that state. Instead, he claims that mental concepts can arise out of the *process* of simulating others. This alternative proposal rests on his belief that the majority of simulation work is in fact carried out by relatively superficial imitative mechanisms (such as the automatic muscular mimicry of others' facial expressions), that operate in the absence of such concepts. While this may provide a part answer to how we recognise mental states such as emotions in others[8] , it is not clear how such an argument could account for other mental states such as beliefs, which in large part are unobservable. The problem appears to remain; simulation theory is merely an account of a *procedure* used in ascribing mental states to others. And such a procedure must in general assume a prior theoretical understanding of mental states.

A second point to be made is that mental simulation is typically articulated by its advocates as a form of *modelling,* where we use ourselves as a model of the other in order to explain and predict the others' actions. Researchers such as Goldman (1989), Harris (1989), and Ripstein (1987), highlight the ways in which models are used in other domains such as engineering to determine whether various events would produce certain effects on their real counterparts. Such employment of models they claim, supports their argument that using oneself as a model is a legitimate method by which to achieve understanding of others. However, a model of a bridge to take one example, can only be used to demonstrate the connections between an event (a hurricane), and an effect (the collapse of a suspension bridge), if the model is similar to the bridge in question in all relevant respects. Otherwise the demonstration is empty. And determining which similarities are relevant requires theoretical knowledge. Hence, if using oneself as a model or analog of another operates in the same manner as engineering models, then as Gordon (1992) points out, it too must stand on the premise of similarity in theoretically relevant respects. Therefore, it could be argued (see Dennett, 1987) that simulation is not really in direct competition with the theory theory, since simulation requires theoretical knowledge in order to be justified, and hence presupposes a theory.

Gordon (1992) thinks such a claim is only relevant to what he terms the "model model of simulation", which in contrast to Goldman (1989) and Harris (1989), he explicitly rejects. In Gordon's judgement, we simply utilise part of our own cognitive system off-line to 'generate' a decision. And since we are not making any implicit inference from ourselves to another, there is no need to postulate a theory to justify such an inference. Gordon however provides few details as to how in fact our practical reasoning system generates such decisions. We are told that the system "makes up its mind" what to do. But what does 'making up its mind' involve? It is plausible to entertain Fodor's suggestion (cited in Stich & Nichols, 1992), that our practical reasoning system generates a decision from beliefs and desires by exploiting an internally represented theory. At the very

8 Here Gordon is alluding to the fact that emotional contagion displayed by infants clearly precedes any capacity to attribute emotion to others (see Gordon 1992, p.25).

least, such a suggestion would seem to support the view that simulation is dependant on the existence of an underlying theoretical structure.

A final reason why mental simulation would seem to presuppose a theory, is drawn from Paul Churchland's assessment of the plausibility of this alternative account. He concludes that even if simulation can be shown to allow for the prediction of others' behaviour, it is incapable of providing any *explanatory understanding* in the absence of an underlying theory. To emphasize his point, Churchland provides the following illustration:

"Suppose I were to possess a marvellous miniature of the physical universe, a miniature I could manipulate in order to simulate real situations and thus predict and retrodict the behaviour of the real universe. Even if my miniature unfailingly provided accurate simulations of the outcomes of real physical processes, I would still be no further ahead on the business of *explaining* the behaviour of the real world. In fact, I would then have two universes, both in need of explanation" (1991, p.46).

According to this view, in order to use oneself as a model of another, one must be able to explain one's own behaviour, and simulation provides no such explanatory understanding. Such understanding according to Churchland, demands "a nomic framework that allows one to appreciate the general patterns that comprehend the individual events" (Churchland, 1991).

Advocates of simulation theory have responded to such a claim by pointing out that a model can be used to simulate counterfactual conditions in order to test their influences and hence enable one to pick out the relevant causal factors in a given situation. Goldman (1989) appears to hold that such an ability to eliminate various alternative hypotheses is sufficient to provide us with an explanation of the event in question. Gordon (1992) is rather more cautious in his reply to Churchland's objection. He concedes that in discussing physical phenomena generally, a simulation alone is insufficient to provide an adequate explanation, if as Churchland implies, explanation involves not only a discrimination of the causal factors at work, but also an understanding of why the cause had the effect it did. Such a concession however, does not move Gordon to reject his claim that simulation avoids the need for positing a theoretical framework. Instead he proposes that explanatory understanding of human action is of a different kind to explanation in other domains, and therefore avoids Churchland's objection. In short, Gordon believes that the explanatory understanding we look for when attempting to understand why a person acted as she did, is in fact *empathic* understanding:

"The empathic method gives us all the explanatory understanding we want; it (not a law) enables us to see the connection between explanans and explanandum" (1992, p.29).

Such a proposal brings us almost full circle, since it stands as a statement of continued motivation to view our understanding of human action as distinct from understanding in other domains and hence not dependent upon theoretical knowledge. In contrast, the arguments outlined in this section in favour of the theoretical view have been based on a perception of our psychological knowledge as fundamentally the same as our knowledge of the rest of the world. Just as we learn about the outside world, we also come to understand the activities of our inner states by a process of conceptual development, characteristic of our attempts to make sense of phenomena generally. In short, an understanding of how we function is achieved by a process of theory construction. And if it can be accepted that any appeal to empathy demands an initial understanding of oneself, then inevitably one returns to the notion of a theory.

3

The child and folk psychology

"Let us imagine a being, knowing nothing of the distinction between mind and body. Such a being would be aware of his desires and feelings but his notions of self would undoubtedly be much less clear than ours. Compared with us he would experience much less the sensation of the thinking self within him, the feeling of a being independent of the external world. The knowledge that we are thinking of things severs us in fact from the actual things. But, above all, the psychological perceptions of such a being would be entirely different from our own. Dreams, for example, would appear to him as a disturbance breaking in from without. Words would be bound up with things and to speak would mean to act directly on these things. Inversely, external things would be less material and would be endowed with intentions and will. We shall try to prove that such is the case with the child. The child knows nothing of the nature of thought, even at the stage when he is being influenced by adult talk concerning "mind", "brain", "intelligence" (Piaget, 1960 p.37).

If it can be accepted from the proposals outlined in Chapter 2 that folk psychology is theoretical in nature, then one needs to ask whether it is appropriate to credit young children with a folk theory of mind. Traditionally, young children's thought has been depicted as the very antithesis of rational thinking, that is, as preconceptual, acausal and adualistic (Johnson, 1988). Essentially, children have been viewed as fundamentally different types of thinkers than adults, with cognition seen to undergo qualitatively different forms as the child proceeds through a well defined sequence of developmental stages.

The child-as-scientist metaphor distinguishes itself from traditional depictions of childhood thought, by striking an antithetical pose to any such demarcation between children and adults. By implying that children should be credited with the kinds of theoretical knowledge and forms of inquiry found in institutionalised science, the analogy effectively traverses the dividing line traditionally erected between child and adult thought. On this view children are not impoverished thinkers, rather in their everyday attempts to comprehend the world they bear a striking resemblance to adult scientists.

The aim of this chapter is to indicate the plausibility of the child-as-scientist metaphor by focusing on the young child's development of ideas about the mind and its relation to the world. The characterisation of childhood thought that emerges from such deliberations, challenges the traditional depiction of the child as an inferior thinker and provides some provocative empirical evidence in support of child-scientist comparisons. Specifically, tracing the child's development of an understanding of mind indicates that the child can be seen as an intuitive scientist in two important ways; firstly with regards to the content of their knowledge, and secondly in terms of the process by which they go about exploring the world.

3.1 Adherence to a theory of mind

In looking to prove claims regarding children's understanding of folk psychology, a primary concern is whether or not their knowledge rests on the specific ontological commitments of this mentalistic framework. In our everyday attempts to make sense of phenomena we are commonsense realists; that is, we ascribe to the view that a world exists independently of our thoughts of it, and hence draw a fundamental distinction between internal mental phenomena and external physical and behavioural phenomena. If young children are to be reasonably credited with anything like an adult theory of mind, they would need to demonstrate an appreciation of this demarcation between the internal mental realm and the external physical realm.

Traditionally, the proposal has been that young children fail to honour any such distinction. Rather they have been characterised as adualistic, treating the mental and physical realms as a single, undifferentiated whole up until 6-7 years of age. According to Piaget, two principle confusions define children's thinking in this early period. The first, is to perceive thought as material and to identify it with external behaviour such as talking; and the second is to equate thoughts with their corresponding physical referents, prompting the claim that ". . . the child cannot distinguish a real house for example, from the concept or mental image or name of the house" (Piaget, 1960 p.55)[9] . Recently however, this depiction of

[9] The term 'childhood realism' coined by Piaget, has come to identify this general view of young children's thought. The reference to realism is an attempt to highlight the fundamental deficiency in children's thinking, that is, the failure to grasp the mental-real distinction and hence the

children's understanding of mental phenomena has been challenged by a body of research which indicates that even very young children are knowledgeable of the basic categories of existence.

Wellman and Estes (1986) found that 3 year olds demonstrate an understanding of the behavioural-sensory differences between mental and physical phenomena, and can use such 'reality criteria' to distinguish between real entities (a dog) and mental entities (a thought about a dog). Young children correctly judge that real objects can be seen, touched, and acted upon, that other people can perceive such objects, and that such objects have a consistent existence over time. Conversely, young children appreciate that mental entities cannot be seen, touched, or acted upon, and cannot be experienced publicly or consistently (Wellman & Estes, 1986). In addition, young children's knowledge of the mental realm was found to extend beyond such judgements to include some recognition of the 'positive' features of mental phenomena, for example their capacity to be transformed or manipulated by thought alone (Wellman & Estes, 1986).

Furthermore, contrary to Piaget's claims, it appears that young children are not prone to more subtle misconceptions regarding the distinction between mental and physical entities. Three year olds were found to be capable of differentiating between mental entities and real, but absent, physical objects (Wellman & Estes, 1986). They appropriately distinguished mental entities from "close impostors" such as shadows, air, and smoke, which are real but intangible entities (Estes et al, 1989). Relatedly, they had no trouble differentiating between the mental image of a particular object and a 'close impostor' of another kind, namely an inaccessible physical representation of the object (a photograph hidden in a box), suggesting that they apprehend the distinction between mental and physical representations. Moreover, in all of the above examples, children gave very different sorts of explanations for physical items (location-possession explanations), in comparison to mental items for which they gave mental explanations (Estes et al, 1989). Collectively such findings indicate that young children's understanding of mental phenomena is not hopelessly confused. Rather, by drawing informative contrasts between children's conceptions of mental and physical phenomena, this research presents compelling evidence that even 3 year olds are capable of making the appropriate ontological distinction central to folk psychology.

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attribution of real properties to mental entities. Use of this term has been avoided here so as to prevent confusion with the alternative proposal being put forward, namely that children are commonsense realists -- a claim which rests on their capacity to make the distinction between thought and a real world which exists independently of such thought.

In order to substantiate the claim that young children possess a theory of mind, it is also necessary to address children's causal understanding of human action. Folk psychology views the generation and interpretation of human action in mentalistic terms, that is, actions are seen to result from the interplay between an actor's beliefs, desires, and intentions. Evidence that pre-school children understand mental entities to be ontologically distinct from physical entities, suggests that they may very well possess a basic conception of the entities encompassed by folk psychology. However to qualify as a theory of mind, young children need to exhibit an appreciation of psychological causality.

In order to evaluate children's ability to invoke the internal mental states of an actor as a way of understanding human action, it is necessary to first consider the cognitive competences or abilities that underlie our commonsense view of the world, most notably our capacity for meta-representation. Indeed, as a number of researchers have noted (Forguson & Gopnik, 1988; Gopnik, 1990; Perner, 1988), the ability to meta-represent, that is to reflect on one's own representational system, is an essential development that enables the child to move from merely having mental representations, to reasoning causally about such representations in terms of their role in determining behaviour. When do such abilities emerge in children? Evidence from a wide variety of sources suggests that by 18 months children have developed the capacity to reflect to some extent on their own intellectual processes. Unlike young infants whose representations seem to be tied directly to their experience of the world, the child at 18 months has developed the ability to consider alternatives to reality and to contrast such alternatives with the existing state of affairs. The suggestion made by Forguson and Gopnik (1988), is that this ability for constructing counterfactual representations is closely linked to the child's emerging capacity for meta-representation. Such a proposal provides a coherent explanation for a wide variety of achievements witnessed in this period. For example, evidence of the invention of intelligent solutions to difficult problems by 18 month olds indicates meta-representational abilities at work. According to Gopnik (1982), when young children invent new solutions to problems they seem to carry out experiments in their heads, that is mentally run through hypothetical courses of action and their associated outcomes without actually having to experience either the actions or their outcomes.

Similarly, the emergence of pretend play in 18 month olds (Leslie, 1988), the growing recognition that people may see the world differently from themselves, as witnessed in visual perspective taking tasks (Flavell et al, 1981), and indications that young children use early words to refer to aspects of their plans and encode abstract relations between their aims, actions, and the world (Gopnik, 1982), can all be accounted for by attributing meta-representational abilities to the young child. A further body of supporting evidence that young children demonstrate the capacity for meta-representation, is drawn from the work of Wellman and Estes (1986) referred to earlier. Their findings that 3 year olds distinguish between dreams, images, and thoughts, and real objects, and provide extended explanations to justify their distinctions provides yet another indicator that young children have the ability to form second-order representations, and contrast representations with reality.

If young children do possess some meta-representational abilities, then it seems plausible to consider whether they share much of our basic folk psychological causal-explanatory framework for human action. For example, if children are told of an actor's beliefs and desires they should be able to predict her behaviour. Conversely, if children are asked to explain an action, they should do so by appealing to beliefs and desires. Evidence from investigations of belief-desire reasoning in young children (Bartsch & Wellman, 1989; Wellman & Bartsch, 1988), suggests that by 3 years of age children do appeal to a mentalistic psychological framework for the explanation and prediction of behaviour. Three year olds demonstrate an understanding of beliefs and desires as distinct mental states, as well as recognising the links between these two constructs, namely that they are jointly responsible for determining a person's actions (Wellman & Bartsch, 1988). Given one half of the causal equation (an actor's beliefs and desires), children as young as three can predict the appropriate behavioural outcome (Wellman & Bartsch, 1988). These children also demonstrate the flexibility to work backwards; if told of a character's action, "Jane is looking for her kitten under the piano" and then asked "Why do you think she is doing that", young children reply by framing their answers in terms of what the protagonist wants and thinks (Bartsch & Wellman, 1989).

This, however, is not to say that the early belief-desire reasoning scheme utilised by 3 year olds rests on an understanding of psychological causality that is the same as that possessed by older children or by adults. A point of much debate in the literature is whether or not children of this age understand the mind as a representational system. The commonly held view is that 3 year olds possess a mentalistic but non-representational model of the mind, and that representational understanding only emerges about a year later. Forguson and Gopnik (1988), for example, suggest that the crucial difference between 3 year olds and older children is that 3 year olds fail to perceive the relation between the mind and external reality as one which is mediated by mental representations. According to these authors, 3 year olds are only capable of contrasting the real world with the 'non-real' mental world; they do not understand that reality is itself represented. However, it is proposed that the findings of Wellman and Bartsch (1988) that 3 year olds were 82-90% correct in predicting a character's action on the basis of his belief that was discrepant from their own and from reality, and in predicting a character's action on the basis of his belief which changed over time, suggest a more gradual progression of representational awareness. Specifically, these results indicate that 3 year olds recognise that belief is subject to diversity and change, which could be seen as the beginning of an understanding that beliefs and desires are not objective features of the world, but rather are a function of representations.[10]

A final point on which to compare children's understanding of the mind with our adult folk psychology, relates to questions of coherence. Like its framework-theoretical counterparts in science, folk psychology provides us with an interconnected network of beliefs, which enables us to comprehend an important aspect of our everyday world - the actions of those around us. The coherent nature of our commonsense mentalism becomes readily apparent when we consider the interrelationships between the various constructs entailed by our folk psychology. In brief (see Wellman, 1990 for details), our physiological states and what Wellman terms "basic emotions" are generally taken to be the catalysts for our desires, while our beliefs are seen to stem from our perceptions of the world. According to our everyday theory, the interplay of these beliefs and desires cause us to act, and the outcomes of our actions can result in a range of emotional reactions, for example happiness, sadness and surprise. A schematic presentation is given in Figure 2 below. An inspection of the interrelated nature of our adult folk psychology leads one to question whether the young child's understanding of the mind also displays this coherence.

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[10] Not everyone agrees with the account just sketched. For example Perner (1988, 1991) vigorously rejects the proposal that 18 month olds evidence some meta-representatonal abilities, seeing their achievements to result instead merely from an ability to construct and use multiple models. In his view, the capacity for meta-representation only emerges at around 4 years when children demonstrate an explicit understanding of mental representation. Stated as such, I see two problems with his account. Firstly, by attributing an 'all or none' quality to meta-representation as a capacity which is present at 4 years and not before, Perner fails to adequately account for 3 year olds intermediate level of understanding of representation as demonstrated by Wellman and Bartsch (1988). Secondly, it would appear that Perner's motivation for locating the onset of meta-representation at 4 years stems in large part from the desire to tie meta-representation as a form of meta-cognition to explicit awareness. However the necessity of conscious reflection for meta-cognitive activity now seems doubtful (Karmiloff-Smith, 1986).

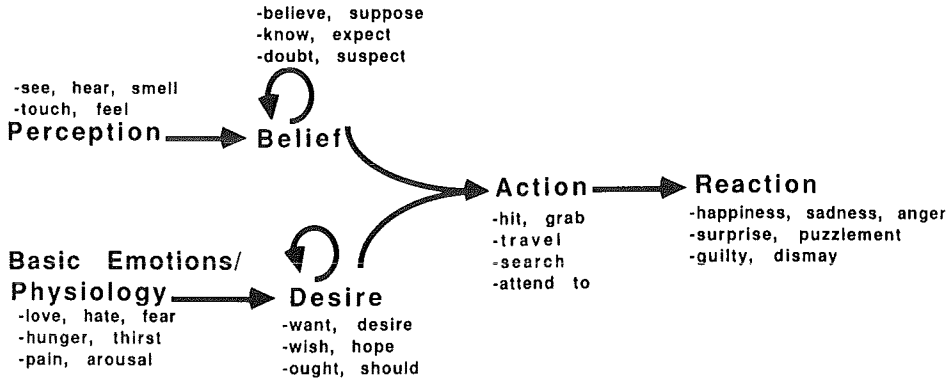

Figure 2 Belief-desire psychology: a schema of the organisation of the constructs of our everyday theory of mind (from Wellman, 1990).

By 3-4 years, it appears that children's folk psychological understanding does comprise an interconnected network of constructs, and one that extends beyond the basic belief-desire-action triad discussed earlier. According to Wimmer et al (1988), young children not only manifest the ability to draw on beliefs and desires to predict people's actions, they also acknowledge the role of perception in this causal sequence, recognising its importance in the initial formation of people's beliefs about the world.

Emotion figures prominently in our everyday psychology, and therefore it is not surprising to find that by 3 years of age children have also developed a coherent understanding of the relationship between the mind and emotion. The work of Harris et al (1989) demonstrates that children recognise it is not the objective features of the situation itself, but rather a person's appraisal of that situation that governs their emotional reactions to it. Their findings suggest that children's understanding of the causes of emotion extend far beyond a facile 'situationist' interpretation of links between various situations and associated emotions. Rather, in their appeals to characters' beliefs and desires to explain and predict emotional reactions, children evidence an understanding of the causal organisation of emotion that is fundamentally the same as adults.

In sum, such evidence implies that children's understanding of the mind is appropriately interrelated and interconnected. Furthermore, when asked to explain mental entities children often reply by framing their explanation in terms of other mental entities, suggesting that their understanding is also "mutually self-defining" (Wellman, 1988). For example, Wellman & Estes (1986) found that children as young as three tended to identify mental terms by appealing to their similarity to other mental terms. Overall, these examples can be seen to lend credence to the view that children's folk psychology is coherent, since they demonstrate how the various constructs within our everyday psychology make reference to one another, and how children evidence knowledge of this theoretical framework from a young age.

From the evidence cited, it would seem that even young children are engaged in much the same folk psychological enterprise as adults. Their understanding rests on the requisite ontological distinctions, it displays coherence, and provides a powerful causal-explanatory framework with which to comprehend human action. For many developmentalists the analogy between children's knowledge and theories in science ends here. Yet there is another sense in which children's knowledge may be profitably viewed as theory-like, namely in terms of the processes by which it undergoes development. If we turn to the more dynamic characteristics of theories mentioned in Chapter One that are involved in the process of theory change in science, we can ask whether the theory analogy is sustained. That is, we can investigate whether these features are also apparent in children's developing understanding of mind.

3.2 Conceptual change as theory change

A recent collation of empirical evidence bearing directly on this question, is presented by Gopnik & Wellman (1992), who conclude that the gradual transition from one view of the mind to another between the ages of 2.5 and 5 years, manifests features characteristic of theory change in science. In contrast to older children, the child at 2 years of age utilises what may be termed an early desire-perception theory or "simple desire psychology" (Wellman, 1991). Such an understanding lacks any concept of belief. Furthermore, desire and perception seem to be understood as simple non-representational causal links between the world and the mind. In this way 2 year olds' understanding is quite different from 5 year olds' belief-desire psychology, which rests on a conception of internal cognitive states representing truths about the world (Wellman, 1991). What intermediate processes are evident in this change from an early desire-perception theory to a representational understanding of mind?

Initially young children with this non-representational theory often deny the existence of counter evidence, prime examples being cases of misrepresentation. To illustrate, Gopnik & Astington (1988) presented young children with objects that looked to be one thing but were really another, such as a 'rock' made of sponge. These children generally said the object was a rock, before touching it and discovering its real nature. But when asked what they had thought the object was when they first saw it, the children tended to say that they had thought all along the object was a sponge. In short, they denied that their representation had changed.

While children may insulate themselves from such counter evidence for a period of time, eventually the accumulated weight of such evidence forces changes to the early theory. In 3 year olds there is evidence of an 'intermediate phase' in which understanding of the existence of representational states is sometimes demonstrated, but only in certain situations and only for particular mental states. At around three children develop an account of belief (Wellman, 1990); however such an account is initially non-representational in character, being modelled on an earlier understanding of desire and perception. Hence, as Gopnik and Wellman point out, the concept of belief seems to be founded on a reworking of earlier theoretical constructs. At this stage belief is clearly not the central theoretical construct of the 5 year old's theory, but rather appears to function as an auxiliary hypothesis. That is, while realising that people can have mental states such as belief, 3 year olds do not yet seem to recognise the centrality of belief to a causal account of human action. The first signs of misrepresentation also appear to develop in the familiar contexts of desire and perception, and as with the concept of belief, are not widely applied. Rather in mirroring the scientific case, the new idea so crucial to the later representational theory of mind initially functions as an extension of the earlier theory, and is used only to deal with what appear to the child to be isolated anomalies. Finally, in the five year old, one can witness evidence of a reorganisation of the child's knowledge into a coherent representational theory of the mind, one characterised by the recognition that "all mental life partakes of the same representational character" (Gopnik & Wellman, 1992, p.153).

This sketch has provided only a brief glimpse of how young children reorganise their knowledge of the mind. Nevertheless it would seem sufficient to highlight some compelling similarities between the process of conceptual change in the child, and the process by which knowledge undergoes change in science. In a similar manner to scientists, children initially ignore or tolerate anomalies, then construct auxiliary hypotheses to deal with the counter evidence, utilise a new idea in a restricted way, and eventually reorganise their knowledge so that the coherency and explanatory power of the new theory is revealed (Gopnik & Wellman, 1992).

For some researchers however, drawing on theory change in science to illuminate the process of knowledge development in children amounts to an overuse of the theory analogy, resulting in knowledge being misconstrued as 'invented' or constructed by the child, when in fact it is best classed as innate. For example, there is a general concern amongst developmentalists over the implausibility of a scenario in which children all arrive at a representational theory of mind at approximately the same time via a process of individual theory construction. A far more likely proposal, contend some, is that what looks like a process of theory change is in fact the unfolding of a predetermined sequence or innate module.[11] On this view, the changes witnessed in children's ideas about the mind are best conceived in terms of *maturation* rather than theory construction.

Does evidence suggesting that children come to accept similar ideas about the mind at around the same time in development necessarily require a maturational explanation? Not according to Gopnik (1993), who argues that the uniformity in children's developing knowledge of the mind can be accounted for on a theory formation view in light of three features of the developmental situation.

Firstly and rather obviously, children begin in similar 'starting states' to one another.[12] However, what *is* interesting is the richness of this innate cognitive endowment. It appears from infant research on social referencing, joint visual attention, and imitation (Baron-Cohen, 1991; Butterworth, 1991; Meltzoff & Gopnik, 1993), that we do not have to 'discover' the links between ourselves and others, rather these links may be specified innately. Similarly, our folk psychological explanation of behaviour in mentalistic terms appears to be facilitated by an innate 'head start'. In interpreting human action, children give no indication of initially framing their explanations in behaviouristic terms; rather it would seem that we begin life with some, albeit primitive, sense of psychological causality. One consequence of such an endowment would undoubtedly be a certain degree of uniformity in the subsequent pattern of development. Hence, while not corresponding to a set of rigid constraints on final possibilities (the modularity view of mind), such a rich innate starting state would very likely ensure that in our early theoretical deliberations we head off down a similar path.

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[11] Leslie (1987) is perhaps the most prominent advocate of the proposal that our psychological knowledge is encapsulated in a theory-of-mind module.

[12] Gopnik (1993) makes a clear distinction in her work between "modularity nativism" (which she rejects) and what she terms "starting-state nativism", the view that our native endowment acts as a foundation for our developing psychological understanding, but does not predetermine the final form such understanding will take.

A second reason why we should anticipate a certain consistency in the pattern of children's knowledge development, relates to their ability to construct coherent knowledge structures. According to Gopnik (1993), not only do children begin in similar starting states, they also have similar theory formation abilities and hence will go about operating on the world in a similar manner. While accepting Gopnik's point, it would seem as important to recognise the cognitive competences *underlying* our ability to construct a commonsense theory of the world, most notably our capacity for meta-representation discussed above, which develops in children at around 18 months. Given the centrality of this capacity to our understanding of psychological causality, its emergence at 18 months could conceivably give the impression that an innate theory-of-mind module is unfolding. Indeed it is at precisely this point in development that Leslie (1987) postulates the maturation of an innate module to occur. To argue as Leslie does that the *content* of our psychological understanding matures at 18 months is however, quite different from the claim presented here, namely that one cognitive capacity underlying the child's ability to construct a theory of mind becomes evident at this time.

A final reason why even in the absence of an innate module we would expect uniformity in children's developing knowledge of mind, concerns the similarity in the patterns of evidence children receive. If it can be accepted that children are likely to have similar experiences of mental causation, then the observation that children develop a representational theory of mind at around 5 years could, Gopnik argues, be likened to the occurrence of independent discoveries in science; where similar conceptual developments in a field at a certain time, and a similar accumulation of evidence, lead scientists to make independent but 'synchronized' discoveries.

Whether or not one finds Gopnik's analogy plausible, it serves to make one point clear. Any viable argument for the view that conceptual change in children mirrors theory change in science would have to demonstrate not only that knowledge restructuring is taking place, but that these changes in the young child's theory are related to their experience. Obviously a dramatic demonstration of this relation, would be a body of cross-cultural research in which children who experienced different evidence regarding the relation between the mind and the world, constructed different folk psychological theories as a result.[13] While I am unaware of any such research, one study that does

[13] Here I am thinking of a situation in which different cultures are found to organise the basic constructs embodied in a mentalistic construal of human action in a fundamentally different way to the schematic presentation outlined in Figure 2 above. Is this a likely scenario? Intuitively, the basic belief-desire-action triad that undergirds our adult folk psychology would seem to be fundamental

speak on this point provides preliminary support for the parallel between conceptual change in children and theory change in science. Bartsch and Wellman (1989) in their investigation of 3 year olds' understanding of false belief (tasks which 3 year olds typically fail), found that making counter-evidence particularly salient to children induced application of the new theoretical idea. The fact that it is possible to *accelerate* the rate of development of children's understanding by presenting counter-evidence in an explicit fashion, would seem to recommend a theory formation account over other alternatives (e.g., an internal maturation view). An investigation of a naturally occurring example of this situation had similar findings. Young children who have the benefit of interaction with siblings, appear to demonstrate an accelerated understanding of false belief in relation to only children (Perner, Ruffman, & Leekam, 1994).

While these studies are in line with a theory formation account, the most compelling evidence for the claim that conceptual change in children resembles theory change in science is to be found in a closer examination of the pattern of development occurring between 2.5 and 5 years that was briefly sketched above. In focusing on the conceptual moves executed by the child in the passage from a primitive non-representational desire psychology to a fully representational theory of mind, one is immediately struck by the logical sequence in the progression of ideas, with each conceptual advance seemingly acting as a 'springboard' for the next (Gopnik, 1990). For example, awareness of the representational character of all mental life can be seen to originate in the child's ability to form counter-factual representations which are first utilised in pretend play. The possibility of alternative representations in the child's imaginary world, appears to act as a precursor to the possibility of alternative representations in the real world, seen initially in the child's recognition that other people may have a different view of the world to themselves. Once established, this idea of alternate representations seems to form the foundation for a developing awareness that people's representations (including one's own) are subject to diversity and change. The concepts of representational diversity and change are initially applied by the child in the simpler cases of perception and desire. In the final phase of development these concepts are extended to the case of belief as the child comes to understand that even people's beliefs will not always correspond to the way the world is, and that such discrepancies are indicative of their representational status.[14]

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to any attempt to interpret human behaviour, and hence would very likely extend across cultural boundaries.

[14] This picture of the child's developing understanding of mind is further endorsed by the numerous transitional phenomena seen in 3 year olds as they attempt to negotiate the path from a nonrepresentational to a representational theory of mind. Being in the midst of a transition from

Moreover, researchers investigating this progression in the child's understanding of folk psychology have commented on its recursive nature (Gopnik & Wellman, 1992). Not only does knowledge development proceed in a logical sequence, but far from 'unfolding' in any passive way, children seem to build up their understanding of the causal structure of the mind, and then reflect on this knowledge, reorganising it into a consolidated and generalised framework. For example as highlighted above, the idea of representation initially seems to function in an ad hoc manner, tagged on to the child's early theory as a way of dealing with what at the time appear to be isolated anomalies. Through the partial application of this idea, the child seems to build up knowledge of the representational nature of mental states, which eventually leads to a restructuring of the initial theory and its auxiliary hypotheses into a coherent representational understanding of mind.

In this process of restructuring, children's psychological understanding in a similar manner to scientific knowledge can be seen to undergo qualitative change. The simple desire-perception theory held by 2 year olds, constitutes a conceptual system that is very different to the 5 year old's representational understanding of mind. Not only is the younger child's theory devoid of any concept of belief, but desire and perception are understood in non-representational terms. A maturational account that characterised children's knowledge acquisition purely as an enrichment of innate structural principles (Spelke, 1991), would seem inadequate to account for this pattern of development. For the conceptual leap seen in older children would not appear to be simply a matter of adding more concepts or additional information to the existing framework. Rather, in moving from a non-representational view to a fully representational theory of mind, children in a similar manner to scientists are developing qualitatively new conceptual structures.[15]

Furthermore, if as suggested by the theory analogy children's beliefs about the mind are causal-explanatory in character, then the conceptual transition between 2.5 and 5 years can be seen to afford children increased explanatory power. By embracing a fully representational theory of mental states, the 5 year old has at

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one view of the mind to another, these children are found to hold both representational accounts of desire and non-representational accounts of belief (Gopnik & Wellman, 1992).

[15] Another pointer to theory development is the child's natural language in this period. The semantic changes that occur can be seen to mirror semantic change in science (Gopnik, 1982). Mental terms appear to act as theoretical terms for the child - they are tied to their immediate cognitive problems and undergo change as the child's theory changes. For example, before 3 years of age children make extensive use of mental terms for desire and perception. Terms relating to belief however, only begin appearing in the child's lexicon at around 3 years when an account of belief is developed.

her disposal a range of explanations and predictions that were not previously possible. Cases of false belief and misrepresentation for example, that were inexplicable at 2 years of age, can be readily interpreted at 5 years in light of the newly developed understanding of the representational status of mental states. In effect, by making the conceptual transition from one view of the mind to another, children are achieving an increasingly more accurate approximation of the mentalistic causal mechanisms that we as adults postulate to be responsible for human action.

Collectively, the pattern of developmental changes in the child's understanding of the mind suggests that such progression is best perceived as changes in theory. This conclusion is further supported by similar patterns of development in children's understanding of biology (Carey, 1985b), intuitive physics (Karmiloff-Smith, 1988), and observational astronomy (Brewer & Samarapungavan, 1991). In all of these domains, children are seen to actively integrate information into coherent knowledge structures which in turn provide them with a form of cognitive economy. These structures undergo qualitative change and they are causal-explanatory in character, providing children with the explanatory and predictive capacities they require in their everyday attempts to make sense of the world.

In sum, by extending the theory analogy to the process by which children's knowledge undergoes development, we see not only that children hold theories but that many of the features characteristic of theory change in science, are also apparent in the young child's developing understanding of mind. Adopting a theory perspective in this stronger sense carries with it certain assumptions regarding the cognitive capacities of young children; assumptions that serve to challenge traditional depictions of children as fundamentally different types of thinkers and learners to adults. Specifically, in likening conceptual change in children to the process of theory change in science, the young child is cast in the role of an active theoriser; constructing a conceptual framework with which to grasp the world and modifying this framework to achieve an increasingly effective ordering of experience. The resemblance to scientists in their attempts to advance knowledge would seem compelling.

3.3 The child as an intuitive scientist : a valuable metaphor?

Recently, a number of researchers have endorsed the metaphor of the child as an intuitive scientist as a profitable way of conceptualising children's interaction with the world and their development of knowledge (e.g. Brewer & Samarapungavan, 1991; Carey, 1985b; Karmiloff-Smith, 1988). This view is captured by the following assertion:

"Clearly, children go about their task as true scientists do, building theories about the physical, social and linguistic worlds, rather than reasoning as inductive logicians" (Karmiloff-Smith, 1988, p.193).

In stark contrast however, are those researchers who explicitly reject the suggestion that children's problem solving can be equated with the processes operative in scientific discovery (D. Kuhn, 1989; diSessa, 1988; Solomon, 1983). For example, Deanna Kuhn (1989) takes the following stand:

" . . . the process in terms of which mental models, or theories, are coordinated with new evidence is significantly different in the child, the lay adult, and the scientist. In some very basic respects, children (and many adults) do not behave like scientists" (1989, p.687).

The view put forward for consideration in this study, is that the child-as-scientist metaphor greatly contributes to our understanding of cognitive development, and that the reluctance to endorse this metaphor is a manifestation of two pervasive beliefs. The first concerns the commonplace notion of what it is to do science that was critically examined in Chapter One. The conclusion drawn from this chapter was that critics of the child-as-scientist view are basing their assessment of childhood competencies on an inappropriate empiricist model of scientific rationality. Such a model has served to promote the view that scientists typically reason in accordance with the rules of formal logic, and hence has been largely responsible for the demarcation of scientific and everyday thought. However as I endeavoured to show in Chapter 1, not only does empiricism present a picture of scientific inquiry far removed from the everyday problem solving activities of young children, it has also been soundly criticised by philosophers and historians of science for its failure to capture the reality of scientifc practice. When we reject this empiricist model of science as a suitable framework for child-scientist comparisons and embrace an appropriate realist view, the distinction between science and commonsense diminishes and the suggestion that commonsense learning and scientific discovery are in fact continuous processes moves rapidly to the fore.

The second persistent belief that contributes to an assessment of childhood thought as non-scientific concerns the cognitive machinery of the young child, the implication being that children do not possess the skills required to be considered involved in processes analogous to scientific theorising. As such, this belief is indicative of the more general child-adult distinction that denies that children's thought and methods of inquiry are the same as adults. For example, Deanna Kuhn (1989) suggests that children are deficient in the area of relating evidence to causal theories, and rather than perceiving a common strategy to underlie problem solving endeavours in children and scientists, she suggests that co-ordination of theory and evidence is a skill which shows progressive degrees of mastery. In Kuhn's opinion so-called expert reasoners (Phd candidates in philosophy) employ distinctly different and superior strategies to those of children.

A related claim which contributes to the perceived inferior status of child reasoners revolves around the importance of conscious articulation and conscious control for scientific thinking, intertwined with the suggestion that meta-cognition requires conscious reflection and/or verbalisation. For example, Moshman (1979) in a similar manner to Deanna Kuhn argues that it is not just the content of children's knowledge that changes with age, but also the nature of their theorising. In his view, in contrast to scientists, children demonstrate an immaturity in their theorising about the world which is intimately linked to their lack of meta-cognitive awareness. Similarly Spelke (1991) rejects the analogy between conceptual change in children and theory change in science, on the grounds that the radical qualitative change to children's concepts implied by the analogy requires the meta-conceptually aware theory-building of scientists. The assumed dependence of metacognitive activity on conscious awareness would also seem to be a contributing factor to Perner's reluctance to credit young children with a capacity for metarepresentation (Perner, 1991), and to the arguments of simulation theorists such as Gordon (1992) and Goldman (1992) who view the proposed existence of scientific theorising in children as demanding an anomalous level of precocity.

Such assessments of childhood thought can, it is suggested, be seen to draw support from Piaget's stage-wise analysis of cognitive development, according to which cognition is seen to undergo qualitatively different forms as children proceed through a fixed sequence of developmental stages: sensorimotor, preoperational, concrete operational, formal operational. Because the cognitive structures organising these stages differ so markedly from each other, the theory as Wellman (1990) points outs, effectively defines a series of developmentally different thinkers. Those opposing the child-as-scientist metaphor can be seen to demonstrate a commitment to this definition of cognitive development, by endorsing the passage through a set of well-defined stages as a necessary precursor to obtaining the level of cognitive maturity witnessed in adult scientists. Indeed, both Deanna Kuhn (1989) and Moshman (1979) explicitly cite Piaget's claims concerning the attainment of formal operations as a *new level of cognition,* to support their arguments that children are fundamentally different thinkers and learners than adults.

Piaget's stage-dependent view of cognitive development has, especially in the last decade, been the subject of much debate and reappraisal (see for example Gelman & Baillargeon, 1983; Mandler, 1983; Carey, 1985a). A growing consensus amongst developmental psychologists, further supported by researchers in science education (e.g. Driver & Easley, 1978; Osborne & Wittrock, 1983) is that a content-independent, domain-general formulaton of development is incapable of capturing the true nature of developmental change. More specifically, the view that young children possess distinctly different and inferior mental machinery to adults, has been replaced in much of the recent literature by a strong knowledge-based approach to child development. Researchers such as Carey (1985a) and Brewer and Samarapungavan (1991) argue that the differences apparent in childhood thought when compared to adults, are not due to the child's inability to mentally represent certain kinds of concepts, or because they lack the capacity to undertake certain logical operations. Rather, the differences are seen to result from children's lack of domain-specific knowledge. For example, Carey (1985a) in a concerted attempt to establish in what sense children think differently to adults, highlights how Piaget's seemingly robust experimental demonstrations of both the lack of formal operational thought and lack of causal reasoning in the young child, are in fact concerned with entities in domains where children do not yet possess the relevant domain-specific knowledge. Hence, Carey suggests that Piaget's investigations claiming children's thought processes are qualitatively different from adults' thought processes, actually confound aspects of domain-independent reasoning with theory change in certain domains of knowledge (Carey, 1985a).

Such proposals cohere well with the child-as-scientist metaphor, since they indicate the distinct possibility that children are not immature reasoners compared with adults but rather differ predominantly in terms of the knowledge they possess. Such an argument further implies that in considering children's cognitive development, we should not be primarily concerned with tracking the child's progress through a sequence of age related stages or developmental milestones. Rather our focus should be on detailing the ways in which knowledge is acquired and developed as the child interacts with her world. One researcher whose work has focused on these 'process-oriented' questions is Annette Karmiloff-Smith (Karmiloff-Smith, 1992). Her findings on children's problem solving methods, and the model of cognitive development she has developed based on these findings, hold great import for the proposal that the child can be viewed as an intuitive scientist.

3.3.1 The growth of knowledge: implications of current cognitive theory for the child-as-scientist metaphor

"Children are not satisfied with success in learning to talk or to solve problems; they want to understand how they do these things. And in seeking such understanding, they become little theorists" (Karmiloff-Smith, 1992 p.17).

Generally speaking, in the developmental literature the predominant concern of researchers has been with the content of children's knowledge as opposed to 'process' considerations. As a result, the methods by which children learn about the world have been subject to neglect. This emphasis on content can be seen to have carried over into the child-as-scientist literature, where the development of children's folk psychological knowledge has been characterised in terms of the acquisition of increasingly difficult concepts or the identification of successive 'levels' of representational understanding. However, as Karmiloff-Smith (1992) points out, the specification of macrodevelopmental stages tells us little about what motivates change *between* levels. In effect, such an approach fails to provide an account of how knowledge grows. In order to understand how learning proceeds, Karmiloff-Smith argues we need a micro-developmental approach that focuses on the restructuring of knowledge during actual functioning (Karmiloff-Smith, 1984). By taking a 'process oriented' approach, Karmiloff-Smith specifies a mechanism responsible for cognitive development that provides support for the view that children gain understanding of the world through utilisation of theory.

In her recent book (Karmiloff-Smith, 1992), Karmiloff-Smith draws together ideas she has developed over the years concerning the process of understanding in children. The result is her theory of "representational redescription"- a model of cognitive development, that situates the idea of the child as a "spontaneous theoretician" within a broader conceptualisation of how knowledge grows. Briefly stated, Karmiloff-Smith views development as essentially a move from *implicit* information embedded in efficiently functioning procedures, to progressively more *explicit redescriptions* of that knowledge. She accounts for such development by proposing a model of *representational redescription*, which pivots on the human mind's capacity for metarepresentation. On this model, the progressive flexibility of children's representations is explained by representational redescription - a cyclical process whereby "information already present in the organism's independently functioning, special purpose representations is made progressively available . . . to other parts of the cognitive system" (1992, p.18).

According to this model, development is characterised in terms of three *recurrent phases* (as opposed to age dependent stages)[16] :
During the first phase children are primarily "data-driven", achieving success on the tasks by concentrating on information available in the external environment. In this initial phase such behaviour, while successful, is not generated from any single underlying representation. Procedural success is followed by an "internally driven phase". During this phase, external stimuli are in general ignored and internal representations become the focus of developmental change. During phase three as a result of the reorganisational processes operating in the previous phase, internal representations and external data are brought back into alignment with one another.

Regarding the format of the internal representations involved, Karmiloff-Smith argues for a succession of levels at which knowledge is represented and re-represented:
Implicit (I-level): At this level representations take the form of procedures, activated in response to external stimuli. Level I representations are not available as data structures to other parts of the system.

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[16] This is an important point, for it opens up the possibility of theory construction in some domains (for example folk psychology) at an early age. This aspect of Karmiloff-Smith's theory has however been subject to misinterpretation in the developmental literature. Deanna Kuhn (1989), for example, uses both Piaget's and Karmiloff-Smith's models of development to endorse her proposal that children are incapable of scientific thinking because they have yet to reach the level of cognition that such thought requires. In effect, Kuhn incorrectly takes Karmiloff-Smith's account to be an age dependent stage theory.

Explicit (E-1 level): Once automatisation of these procedures has been achieved, a metaprocess is set in motion, redescribing the procedurally embedded knowledge into an explicit form. This process can be self generating. At this level, the now explicitly represented knowledge is available as data structures to other parts of the cognitive system. It is here that the signs of a cognitively flexible system begin to appear, that is, it is these redescribed representations that serve to form the basis for children's subsequent theory-building.
(E-2 and E-3 levels): Knowledge is further redescribed to become available to conscious access and finally to the point where it is verbally stateable.[17]

In sum, Karmiloff-Smith builds on her claim that the child is a spontaneous theoretician by providing an account of the developmental process through which knowledge is 'made ready' in the mind (i.e., explicitly represented) for subsequent theory building.[18] On this account, children are not seen to think and learn in a fundamentally different way to adults. Rather the hypothesized process of representational redescription operates to make possible cognitively flexible and creative thought in children and adults alike. As such, this current theory of cognitive development (in marked contrast to traditional accounts) can be seen to provide support for the child-as-scientist metaphor, since in its explication of the growth of knowledge it demonstrates that even young children can be profitably viewed as theory builders. More specifically, by endorsing the view that children construct theories, Karmiloff-Smith's work indicates that a fruitful avenue for developing the metaphor lies in a concern with the *methods* or *strategies* children and scientists utilise to advance knowledge of the world. Seeking to develop the child-as-scientist metaphor in this way, by setting up a comparison between the methods of inquiry utilised in science and children's problem solving in the everyday domain, becomes the orienting focus for Chapter 4.

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[17] The fact that Karmiloff-Smith argues for more than two levels of representation is, I think, crucial to the claim that the young child is a theory builder. As she herself notes, developmentalists have tended to perceive the representational system in terms of a dichotomy between implicitly stored procedural knowledge and explicit consciously accessible knowledge that is capable of being stated in a verbal form. This dichotomy, I believe, underlies the claim that young children are not capable of constructing theories since their knowledge is not yet available to conscious access. However, if we accept Karmiloff-Smith's conception of E I level representations in which knowledge is explicitly represented and available as data to the system, but not yet consciously accessible to the child, then we can see a potential base for children's subsequent theorising. Examples of 'E I representations' drawn from studies with children, appear throughout Karmiloff-Smith's book (Karmiloff-Smith, 1992).

[18] In her most recent work (Clark & Karmiloff-Smith, 1993), Karmiloff-Smith turns her attention to connectionist modelling (more specifically PDP or parallel distributed processing) in an attempt to articulate in more detail the functioning of this theory building mechanism and so provide further support for her model of cognitive development.

4

The growth of knowledge in science and commonsense: extending the analogy

As indicated in Section 3.3, the first three chapters of this study have been concerned to demonstrate the plausibility of the child-as-scientist metaphor by tackling two widely embraced distinctions in the literature that threaten to undermine it: the separation of science and commonsense as fundamentally different types of endeavour, and the demarcation of children's and adult's thought on the basis of the young child's deficient cognitive machinery. Having drawn on contemporary philosophy of science and recent findings in the developmental literature to dismantle these distinctions and hence provide support for the child-as-scientist metaphor, this chapter looks at ways to further develop comparisons between children and scientists, so as to engender a fruitful characterisation of knowledge acquisition in childhood.

The proposal to be investigated in this chapter, is that a concern with method informed by a realist perspective on science illuminates compelling similarities between the growth of knowledge in science and commonsense, and hence provides researchers with the most profitable approach to developing the child-as-scientist metaphor. In looking to substantiate this proposal, three lines of support recommend themselves for consideration.

The first of these concerns the recent work on the process of knowledge development in children (Karmiloff-Smith, 1992), that was reviewed above. By characterising children's problem solving in terms of theory formation, and providing justification for this characterisation via investigations of the operation of a mechanism in human cognitive systems that makes such theory building possible, Karmiloff-Smith convincingly overturns the belief that the capacity for theory construction is available only to meta-conceptually aware scientists. In its place she paints a picture of theory formation as the fundamental problem solving mode of humans, and hence alerts researchers to a basis for comparing children and scientists in terms of the process by which they impose conceptual order on the world. A methodological approach to the child-as-scientist metaphor which looks to facilitate a development of this theory-building characterisation can, it is suggested, be seen as a natural extension of Karmiloff-Smith's research indicating that the child is a 'spontaneous theoretician'.

Proposing that as researchers we should be looking to compare children and scientists in terms of the methods by which they attempt to develop knowledge of the world, is also consistent with the tenets of Evolutionary Naturalistic Realism, a theory which serves to provide the philosophical framework for this study. In recognising our situation in the world as creatures evolving from an original position of ignorance, ENR places great import on the task of articulating a realistic strategy for advancing knowledge. Indeed as indicated in Chapter 1, method is central to ENR, for as Hooker (1987) points out, once we recognise the absence of any foundational knowledge upon which to erect an epistemology, a study of the methods of relieving ignorance remains the only path open to us. Moreover, ENR by characterising science as a refined outgrowth of our everyday attempts to make sense of the world, gives us reason to expect continuity between science and commonsense at the methodological level. This in turn implies that an adequate theory of scientific method should also have application in everyday contexts.

A final reason for adopting a methodological perspective to elucidate similarities between children and scientists, concerns the fertility of existing approaches to developing the child-as-scientist metaphor. To date, with the exception of Karmiloff-Smith's work, such developments have been primarily concerned with detailing similarities between children's acquisition of knowledge in a particular domain (e.g., folk psychology, folk physics, folk biology), and the development of knowledge in the history of science. Formulating the analogy in terms of comparisons with the history of science however, would seem to exhibit a number of limitations, most notably the problem of equivalence in juxtaposing changes in the conceptual system of an individual with a model of revolutionary theory change in science, and the subsequent neglect of methodological questions regarding the processes by which human knowers in fact develop such knowledge in everyday and scientific contexts.

In light of the goal of facilitating a fruitful characterisation of knowledge development in children, this chapter will constitute a critical evaluation of these current attempts to extend the child-as-scientist metaphor via comparisons with the history of science. Following this evaluation an alternative formulation of the metaphor will be drafted, in which it is suggested that comparisons between children and scientists are most profitably developed at the methodological level. Utilising a realist perspective on scientific method consistent with Evolutionary Naturalistic Realism, an attempt will be made to demonstrate how an adequate theory of scientific inquiry has the potential to extend Karmiloff-Smith's theory building characterisation of children's problem solving, thereby facilitating an informative perspective on cognitive development. This chapter concludes that investigating the relations between children and scientists from a methodological viewpoint, has much to recommend it as a programme for future research. Specifically, by drawing on a general theory of scientific method to delineate similarities between science and commonsense, researchers are able to take advantage of a theoretical tool designed to illuminate the process of knowledge advance in science to enhance their understanding of the process of learning in childhood.

4.1 The development of knowledge in children and the history of science: evidence for recapitulation?

The aim of Chapter 3 was to indicate the plausibility of the child-as-scientist metaphor by focusing on the young child's development of ideas about the mind and its relation to the world. Having drawn on research suggesting general parallels between children and scientists in terms of both the theoretical nature of their knowledge and the process by which such knowledge undergoes development, the obvious next step is to consider how a development of these child-scientist relations is best achieved. Karmiloff-Smith's theorising outlined in Chapter 3, supports the adoption of a methodological perspective on the child-as-scientist debate, however to date her suggestions regarding such a 'process oriented' approach have not been taken up by researchers in the field. Instead, analogies between science and commonsense have generally been pursued by identifying children's conceptual development with macrodevelopmental stages in the history of science. In these 'history-of-science' comparisons two research camps can be discerned - those who argue for some form of *content* recapitulation between early scientific theories and intuitive concepts, and those researchers who propose that ontogeny-historical development correlations are best explored at the *structural* level. In this section, an attempt will be made to evaluate these two approaches to developing the analogy between science and commonsense, before going on to outline my conception of an alternative way forward for child-scientist comparisons in Section 4.2.

4.1.1 Content analogies: are intuitive theories a 'reinvention' of medieval views?

The idea that the explanatory frameworks held by beginners in certain domains are modern day recreations of early scientific theories, is an intriguing hypothesis and one that has attracted attention from students of the novice-expert shift. Following such a line of inquiry, researchers interested in the changes that occur as novices in particular domains gain expertise, have uncovered some striking similarities between the views that novices bring to instruction and those held by early scientists. Considering that the young child is commonly taken to be the proto-typical novice, these findings hold much import for the comparisons between children and scientists considered in this study.

Of those focusing on content analogies, Michael McCloskey and coworkers (McCloskey, 1983; Caramazza, McCloskey & Green, 1981; McCloskey & Kohl, 1983; McCloskey & Kargon, 1988) provide the most indepth examination of similarities that appear to hold between modern intuitions and early science. Their investigations of people's intuitive ideas about the motion of inanimate objects, suggest that novices in physics hold conceptions of motion which are fundamentally at odds with the basic tenets of classical physics. These conceptions can be seen to stem from a systematic theory of motion which is very resistant to tuition and which interestingly, closely resembles a pre-Newtonian theory of mechanics embraced by medieval scientists in the 14th-16th centuries (McCloskey, 1983). This theory dubbed the "impetus theory of motion", pivots on two central assumptions, both of which are apparent in early scientific writings and in the descriptions and explanations of motion given by modern day students:

i) setting an object in motion invests the object with a force or impetus which is responsible for maintaining the object's motion.

ii) this impetus expends over time, causing the moving object to gradually slow down and eventually come to a halt.

According to McCloskey and Kargon (1988), such resemblances between the two theories are not restricted to this basic idea of 'no motion without force'. Rather, commonalities uncovered between novices' conceptions of motion and those of medieval scientists were found to extend to assumptions concerning the existence of a curvilinear impetus, the cause/causes of impetus dissipation, the question of how an object is invested with an impetus, and the ways in which the internal impetus of a moving object interacts with the external force of gravity.

Correspondences between the content of novices' conceptual systems and those of early scientists have also been articulated in other domains. For example, Marianne Wiser (Wiser & Carey, 1983; Wiser, 1988) investigating the concepts of heat and temperature, presents a case for the existence of parallels between the thermal model held by modern students and the historical model of thermal entities utilised by 17th century Florentine scientists known as 'the Experimenters'. In both models, heat and temperature were found to comprise a single undifferentiated concept which could not be adequately described as simply a mixture of the two modern concepts. Moreover, the novices' concept was seen to share many additional characteristics with the early scientists' concept, as well as constraining explanations of phenomena in a similar manner. Most recently, content analogies have been uncovered by researchers studying young children's developing understanding in the domain of observational astronomy. Vosniadou and Brewer (1994) in their investigations of children's mental models of the day/night cycle, comment on the similarity between the models they attribute to children on the basis of their drawings and explanations of the day/night sequence, and those held by early astronomers.

Collectively, such findings raise the initial plausibility of the claim that meaningful parallels can be drawn between intuitive knowledge and early scientific theories on the basis of content. Given these correspondences, and bearing in mind that the aim of this chapter is to develop the child-as-scientist metaphor, we can ask what advantages are to be gained by pursuing the analogy between science and comonsense via a content recapitulation thesis?

Perhaps the most far reaching benefit of such an approach is the *positive* perception it offers of intuitive knowledge. Using historical theories as a guide to unravelling beginners' concepts in various domains, has the effect of casting the conceptual system the novice brings to instruction in the role of an *alternative* framework to 'official science' (Driver & Easley, 1978). Raising the novice's ideas to the status of a coherent explanatory system that competes with accepted scientific theory as an explanation of phenomena, stands in marked contrast to traditional treatments of novices' intuitions. Prior to comparisons with the history of science, such treatments of the novice-expert shift (also known revealingly as the naive-expert shift) were in the main constructed solely with a view to the accepted or 'correct' account embodied in the expert's conceptual system. This assessment has not surprisingly led to a widely endorsed perception of novices' concepts as impoverished, incomplete, and error-laden in relation to those held by experts (Wiser, 1988).

Such negative characterisations are predicated on the assumption that the conceptual system held by the expert provides the researcher with an appropriate standard against which to assess the adequacy of the novices' beliefs and hence that any deviation from this standard deserves a 'substandard' classification. For this to be the case, novices and experts must share the *same* conceptual system, with the novice merely failing to grasp it in its entirety, or holding some aspects of it imperfectly. The findings of those researchers who have traded a normative approach for a concern with reconstructing the conceptual world view of the novice aided by an historical model however, point to the inaccuracy of this assumption. Investigations of intuitive conceptual systems indicate that like the early scientist, the novice in a particular domain does not hold a substandard version of the later accepted or 'correct' model held by the expert but a different explanatory model altogether, that embodies different concepts and different explanatory mechanisms, and as a result provides an alternative conceptualisation of phenomena in the domain to be explained (Wiser & Carey, 1983; McCloskey & Kargon, 1988).

The reconceptualisation of the novice-expert shift that results from such investigations then, suggests that the history of science provides a positive heuristic for illuminating the richness of intuitive knowledge. Instead of focusing on what the novice lacks against the backdrop of the experts' conceptual system, novices' intuitions are explored in their own right as early theoretical attempts to impose conceptual order on the problem domain. While recognising the utility of medieval science as a working model for detailing novices' explanatory frameworks, there is however a need to query how far analogies on the basis of content can realistically be developed. It would seem implausible from an intuitive standpoint to suggest that modern novices are in fact *reproducing* early scientists' views. Examining the research on content correspondences between students' views and the history of science, indicates further reasons for rejecting a content recapitulation thesis.

Firstly, the similarities witnessed between early scientists' theories and those of modern day students in a certain domain do not amount to absolute identity, with the modern explanatory framework tracing the earlier theory in all of its details. Wiser and Carey (1983) commenting on the possibility of content recapitulation, suggest that an analysis of the relevant conceptual systems in their *entirety* (i.e. including domain, explanatory mechanisms, and individual concepts) would serve to reveal the limited capacity in which early science can be said to re-emerge in modern intuitive views. Vosniadou and Brewer (1994) for example, highlight points of comparison between the early mental models of day/night cycle seen in young children and the categorisation of astronomical objects drawn by Ptolemy, but there is no suggestion that the young child's views are in any way complex enough to be seen as a reproduction of the Ptolemic conceptual system as a whole.[19]

A second reason for disputing a content recapitulation thesis, is the unlikely discovery of parallel sequences of development. To argue for a strict form of recapitulation one would presumably be required to map novices' views to early science at successive points along the developmental path in order to demonstrate that modern students (or children) proceed through similar stages in the content of their ideas to those witnessed in the history of science. To date, researchers investigating content correspondences between the views of modern novices and scientists of an earlier age have focused their attention on singular points in the history of a particular discipline, however those who address the possibility of corresponding longitudinal developments reject the likelihood of comparisons extending beyond mere convergences. Wiser (1988) to take one example, argues that the caloric theory was an important intermediary between the model held by the Experimenters to which novices' concepts were compared and kinetic theory in the history of thermal physics, yet no evidence of a similar developmental parallel is found in modern day students.

[19] McCloskey (1983) and Wiser (1988) do provide evidence for some rather extensive similarities between early scientific theories and modern intuitions, however dissimilarities are also clearly evident. Some of these dissimilarities would seem to stem from the early scientist and the modern novice being exposed to different world views provided by the science of the age. For example, novices' contact with modern scientific ideas results in the construction of beliefs that are markedly different from those held by early scientists (e.g. heat is conceived as energy rather than as a substance (Wiser, 1988); gravity is taken to be a downward force external to the object as opposed to a characteristic (natural heaviness) of the object itself (McCloskey, 1983)).

A final reason for questioning the adoption of a content recapitulation thesis as the preferred avenue for extending the analogy between science and commonsense, is given by McCloskey and Kargon (1988) in their explanation of why correspondences exist between the views of medieval scientists and those held by novice students. According to these researchers, similarities in content are the result of both parties being at the same early stage of theory formation. A number of investigators (Strauss, 1988; Vosniadou & Brewer, 1994; Wiser, 1988) hint that the likely reason for the perceived likeness between early science and intuitive knowledge, is that theoretical beginnings in a scientific domain are usually heavily dependent upon everyday experience and therefore close to the commonsense knowledge held by laypeople. McCloskey and Kargon (1988) go further to cite T. S. Kuhn's structural account of the four levels a discipline proceeds through prior to the establishment of a paradigm and to argue that medieval scientists and novices in physics are operating at the *same level* in this crystallisation process (i.e. level 3 - where theoretical entities are defined and attempts are made to establish causal connections between them). This suggests that the perceived similarities in content in fact result from *structural parallels* existing between the development of knowledge in individuals and the development of knowledge in the history of science. This being the case, a more profitable characterisation of knowledge acquisition in childhood is likely to be secured by concentrating on attempts to develop the analogy between science and commonsense along a structural dimension. Accordingly the work of those researchers who have articulated the analogy in structural terms, becomes the focus of the following section.

4.1.2 Structural analogies: does knowledge acquisition in ontogenesis mirror historical development in science?

While content correspondences between intuitive conceptions and early science exhibit limitations, they are as indicated above suggestive of potentially more informative parallels at the structural level. Specifically, endowing beginners in a conceptual domain with an early framework theory that stands as an alternative to the later explanatory framework held by experts not only serves to highlight the richness of intuitive knowledge, it also says something significant about the nature of the move required between the two conceptual systems. For example by identifying similarities between the young child's cosmology and the Ptolemic conceptual system, Vosniadou and Brewer (1994) emphasise the conceptual divide that separates the young child's views from the currently accepted heliocentric framework. This in turn suggests that navigating the passage between the two will require greater conceptual reorganisation than the simple addition or deletion of one or two isolated beliefs (see also Wiser, 1988). The question naturally arises whether such restructuring takes a similar form to theory change in the history of science?

Susan Carey takes up this question in her research on children's acquisition of biological knowledge and their developing understanding of physical concepts (Carey, 1985b; 1988; 1992; Smith, Carey & Wiser, 1985).[20] Looking to unravel the analogy in more detail with a view to achieving an accurate description of knowledge acquisition in childhood, she focuses attention in her 1985 monograph on three issues: the organisation of children's biological knowledge, the extent to which this knowledge undergoes change, and the ways (if any) in which these changes resemble the restructuring evident in theory change in science. Having articulated the view that intuitive knowledge is organised within framework theories and that reorganisation of such conceptual systems is best seen in terms of conceptual change and belief revision, Carey draws on evidence to argue that the types of changes occuring in the child's knowledge of animals and living things between the ages of 4 and 10 appear to be of the same kind and magnitude as the conceptual restructuring proposed by philosophers (e.g. Kuhn, 1970) to characterise historical development in science.

In making this claim, Carey (1985b) contrasts two different types of restructuring thought to occur during knowledge acquisition. The first labelled 'weak restructuring' which is taken by some researchers to describe the novice-expert shift, involves changes in the relations holding between concepts in a certain domain, and as a result of these changes the formation of new abstract schemata.[21] The second, much more radical sense of restructuring which Carey calls 'strong restructuring', derives its form from contemporary commentary on theory change in the history of science (Kuhn, 1970). On this view of the knowledge acquisition process, three interrelated changes are seen to be involved in the move from one conceptual system to another; these being changes in the nature of the domain, in the type of explanatory mechanisms

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[20] While a number of writers have phrased ontogeny-historical development comparisons in structural terms (Gopnik & Wellman, 1992; Kitcher, 1988; Vosniadou & Brewer, 1994), Carey's research program represents, I think, the most comprehensive development of the proposal that structural parallels exist between conceptual change in children and theory change in science. Hence my evaluation of the profitability of adopting a structural recapitulation thesis for developing the child-as-scientist metaphor will focus on Carey's presentation.

[21] 21 For example, Larkin (1981) has suggested that the differences between novices and experts in the domain of physics can be described in full by appeal to these two forms of change. The more recent investigations of the novice-expert shift considered in my discussion of content recapitulation however, would seem to be more appropriately described in terms of *strong* restructuring.

utilised to account for phenomena, and in the individual concepts at the core of the theoretical system (Kuhn, 1970).

According to Carey, the key difference between these two types of knowledge restructuring lies in the presence or absence of conceptual change. In examples of weak restructuring, concepts do not change, only the relations between them do. In theory change in science by contrast, the core concepts of two successive theories are often found to be markedly different to the extent that attempts to translate terms from the earlier theory to its successor are often thwarted (Kuhn, 1970).

In comparing the evidence for knowledge reorganisation in children's conceptual systems against these two different models of restructuring, Carey concludes that the changes seen to occur as young children acquire biological understanding between the ages of 4 and 10, cannot be adequately described in terms of weak restructuring. The crux of her argument (see Carey 1985b for details), is that the difference between young children's and adults' conceptual systems is not merely a difference in the volume of knowledge held and/or in the relations existing between concepts; there is also evidence of major structural reorganisation involving changes in domain, explanatory structure, and most importantly changes at the level of individual concepts. According to Carey, because of their severe lack of biological knowledge young children organise their understanding of biological processes and activities not in terms of their biological function in sustaining life which they have yet to learn, but in accordance with their knowledge of people and the role these activities play in human intercourse (Carey, 1985b). In Carey's view, 4 year olds do not yet possess an autonomous domain of biological knowledge, so in facing questions about biological processes and activities they inevitably resort to their folk psychological explanatory framework.

During the period 4-10 years, development is construed as the emergence of an intuitive biology out of the parent folk psychological framework, becoming a separate domain of theorising by 10 years of age. Highlighted in this structural reorganisation are changes in explanatory mechanisms (from psychological/social to biological), and conceptual change. Using the move from Aristotelian to Galilean mechanics as a paradigm example of strong restructuring in science, Carey identifies two kinds of conceptual change, *differentiation* and *coalescence,* which she argues are also apparent in children's acquisition of biological knowledge.[22]

Having given some initial indications that the structural analogy holds between conceptual development in children and theory change in the history of science, Carey (1988, 1992) accepts the licence to develop her proposal by calling on a theoretical framework that is often cited by researchers attempting to make sense of strong restructuring in science: Kuhn's doctrine of incommensurability. Couching her proposal in terms of 'local incommensurability' (Kuhn, 1982), she argues that children and adults can be seen to hold "incommensurable conceptual systems" and therefore the passage from one to the other, like similar moves in the history of science, will necessarily involve conceptual change.

The revised view of incommensurability in Kuhn's 1982 paper from which Carey draws her insights, allows her to counter a number of apriori reasons why positing incommensurability between children and adults would seem implausible, the most prominent of these being questions of communication and interpretation.[23] Carey succeeds in showing that these objections can be seen to stem from a more general assumption lying at the heart of a strong nativist position on the development of commonsense knowledge, namely the view that the child's conceptual system is an impoverished *subset* of the adult's and conceptual development is primarily a matter of *enrichment* (see for example Spelke, 1991). As she demonstrates, such a position on cognitive development demands the discontinuity of science and commonsense since it decrees that knowledge acquisition in children does not involve conceptual change. One way in which to counter this nativist perspective would be to provide evidence of continuity between children's conceptual development and conceptual development in science. In arguing for developmental cases of

[22] For example Carey suggests that the child at 4 years due to the paucity of their biological knowledge, fails to differentiate 'dead' (e.g. a dead person) from 'inanimate' (e.g. a stuffed toy). While both are senses of 'not alive', the 10 year old according to Carey can differentiate the two by identifying death as a biological phenomenon involving the cessation of bodily functions. With regard to coalescence, Carey argues that 4 year olds do not possess the biological knowledge necessary to make the connection between animals and plants and hence do not see any reason for including the two in a single category. 10 year olds in contrast recognise the biological basis common to both animals and plants, and this knowledge facilitates the coalescence of the two into the superordinate category 'living thing' (Carey, 1985b).

[23] Kuhn (1982) presents a somewhat amended version of incommensurability in which he argues: a) that incommensurability does not imply incomparability - locally incommensurable theories will still share many terms whose meanings have been preserved during the process of theory change and which therefore provide a basis for inter-theory comparison; and b) 'interpretation' needs to be distinguished from 'translation' - a theory which defies translation can still be comprehended by those holding an incommensurable successor through the processes of interpretation and language acquisition. Equating the two prevents us from seeing how communication between holders of incommensurable theories is possible.

incommensurability comparable to historical cases of incommensurability, Carey (1992) is attempting just that.

From the outline of Carey's research programme given above, it would appear that a concern with structural correspondences between children's knowledge acquisition and the development of knowledge in science, provides a more profitable conceptualisation of the child-as-scientist metaphor than the content recapitulation thesis that was examined earlier. In addition to being intuitively more plausible, positing structural correspondences allows researchers to move beyond a static conception of knowledge and broach the issue of how knowledge changes over the course of development. Such structural comparisons were seen in Chapter 3 to provide researchers with some useful ideas concerning the processes by which children develop knowledge of the world. For example, by drawing on the history of astronomy to highlight characteristic features of theory change in science, Gopnik and Wellman (1992) were able to plot a similar sequence of progression in the preschool child's transition from a belief-desire psychology to a fully representational theory of mind.[24]

More generally, Carey's explicit focus on the organisation of children's knowledge within conceptual domains and the changes to this organisation over the course of development, make it clear that simple accretion of information is not the only alternative to global restructuring models that posit domain general change. A third possibility exists in a domain specific restructuring account that conceives development as principally a matter of theory change from one theoretical framework to an incommensurable successor (Carey, 1992). Developing such a position however, does as Carey is well aware, rest crucially on the strong restructuring model being true, with conceptual change in children being shown to be of the same kind and magnitude as conceptual change witnessed in the history of science. Evaluating Carey's argument for the efficacy of a structural recapitulation thesis in illuminating cognitive development, this is my first point of concern.

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24 A concern with structural correspondences between children's conceptual development and the history of science, also allows researchers the flexibility to make comparisons *across* domains, rather than being restricted by a focus on content to within-domain analyses. In the example highlighted above, Gopnik and Wellman (1992) utilise the Copernican Revolution to illuminate the developmental path of folk psychology. Similarly, Carey looks to the conceptual restructuring that occured between Aristotelian and Galilean mechanics to inform her proposals regarding children's acquisition of biological knowledge.

Does conceptual change in children deserve to be called revolutionary?

In articulating her model of strong restructuring to which she compares children's conceptual development and in her subsequent dependence on Kuhn's notion of incommensurability in her descriptions of knowledge acquisition in childhood, Carey is concerned to show that conceptual changes in children are of the *same sort* as conceptual changes in the history of science. A recent work on the nature of conceptual change (Thagard, 1992) however, casts some doubt on this 'identity' proposal. According to Thagard, who outlines a cognitive theory of revolutionary conceptual change which he then uses to examine historical cases in science, scientific revolutions involve conceptual transformations that far exceed those detailed by Carey to characterise children's knowledge acquisition.

In making this claim, Thagard presents a computational account of concepts in which conceptual systems are seen to be structured primarily via kind and part-whole hierarchies. According to this account, conceptual change can be simple, for example when it involves the addition of concept nodes or links between nodes; or it can be complex, when changes in kind and part relations involving the rejection of existing relations lead to substantial reorganisation of the conceptual system. An example of this more dramatic kind of change provided by Thagard is the restructuring that occured with Darwin's reclassification of humans as a kind of animal (as opposed to a fundamentally different kind of creature argued to be created in God's own image). Thagard labels this kind of change "branch jumping", since it involves the movement of the concept 'human' from one branch of the kind-hierarchy to another. According to Thagard, the only type of conceptual change more radical than branch jumping is a change in the organising principle of the hierarchical tree itself, what he terms "tree switching". This form of change is also illustrated in the Darwinian revolution; under Darwin the notion of kind changed from being one of similarity to become an historical notion, with classification of kind based on common descent (Thagard, 1992).

Drawing on this theory of conceptual change allows Thagard to rank change according to its severity, calculated as a measure of its impact on the structure of the conceptual system as a whole, and as a result identify and compare the degrees of conceptual change that have occured in different theoretical systems. Comparing the history of science and children's conceptual development, Thagard reveals that while all seven of the scientific revolutions examined involved changes of the most radical sort (i.e. branch jumping and/or tree switching), these kinds of conceptual change were notably absent in children's acquisition of biological knowledge. Moreover, the kinds of conceptual change that *were* identified by Carey in children's knowledge acquisition are according to Thagard only simple conceptual changes, since in considering their impact on the structure of the conceptual system as a whole, they result merely in the *extension* of existing relations, rather than their rejection or subjection to a fundamental reorganisation.[25] Thus Thagard concludes that despite Carey's 'identity' proposal, conceptual changes occuring in children are not as radical as conceptual changes that have occured in the history of science. Endorsing this conclusion holds further negative implications for the picture of development that has emerged from the 'conceptual change as theory change' analogy.

Theory replacement: an accurate depiction of knowledge development in ontogenesis?

According to Carey's thesis, knowledge acquisition in ontogenesis and in the history of science exhibit parallel sequences of development; both involve theory change from one theoretical framework to an incommensurable successor. In her case study of children's acquisition of biological knowledge for example, she argues for the emergence of a completely new theory of biology between the ages of 4 and 10 years that replaces the earlier behavioural/psychological theory as an explanatory framework for understanding biological processes and activities. If however as Thagard suggests, children's knowledge acquisition does not involve radical conceptual transformations, then this claim for parallel sequences of development would also seem in dispute.

Such a view seems to be shared by a number of other developmental researchers who reject Carey's claim that children's knowledge acquisition is best seen in terms of theory replacement. Keil (1989) for example, argues that contra Carey, a rudimentary biological theory distinct from folk psychology is present from the earliest years, and hence development consists in the elaboration and differentiation of this pre-existing theoretical framework. Vosniadou and Brewer (1994) also think that Carey's claims are not upheld by the developmental evidence. In their view, knowledge acquisition involves more than enrichment but cannot be adequately described in terms of the direct

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25 This difference between 'simple' and 'complex' kinds of conceptual change can be exemplified by returning to Thagard's characterisation of the Darwinian revolution. There is no indication that children go through a similar kind of branch jumping move to Darwin between 4 and 10 years, recategorising humans as a kind of animal. Children already recognise relations between people and animals (for the young child people are the proto-typical animal), and acquiring biological knowledge does not appear to lead to the abandonment of these relations, merely the formation of new linkages. Thagard tells a similar story for the coalescence of 'animal' and 'plant' between 4 and 10 years. Once again there is no rejection of existing relations, only the addition of new ones, prompting the formation of the superordinate concept 'living thing'.

replacement of one theory with another. Instead their theoretical position appears to take a 'middle road' between these two alternatives, explaining conceptual change in terms of a revolving hierarchy of constraints on children's initial models of the world. Finally Chi (1988) who also investigates the development of children's biological knowledge, posits a more gradual developmental process than one akin to revolutionary change in the history of science. Rather than theory replacement, she argues for a weak restructuring model that sees children undergoing a changing shift in emphasis, whereby the association of 'alive' with movement becomes less salient as biological functions move to the fore.[26]

A review of Carey's claims for structural recapitulation then, would seem to indicate that while similarities do exist between the growth of knowledge in children and theory change in the history of science, there are also some important differences; most notably in terms of the kinds of conceptual change occuring in ontogenesis compared with historical development in science, and more generally with regards to the question of theory replacement as an accurate description of knowledge acquisition in childhood. This in turn indicates that a structural recapitulation model such as that proposed by Carey in a similar manner to content analogies discussed earlier, is best viewed as a heuristic approach that provides a useful working model for children's knowledge development, but is insufficient to support an accurate description of that development in any degree of detail. The reason for this I suggest, is primarily a problem of equivalence that arises in comparing the developmental process in the child with the developmental process in the institution of science.

The problem: institutional change vs individual theory construction

In her comparisons of conceptual change in children with theory change in the history of science, Carey draws on T. S. Kuhn's theory of scientific development in order to account for what are effectively the theorising efforts of individual children. The most prominent example is her reliance on Kuhn's notion of incommensurability, which she utilises to draw attention to the conceptual divide existing between children's theoretical understanding in particular domains and that of adults. In articulating this notion, and in constructing his theory of scientific development more generally however, Kuhn was not concerned with the individual scientist. Rather, his is a structural account of the development of science in general terms, on which it is the *scientific community* and not the

[26] Significantly, Carey while arguing for theory replacement, has elsewhere termed the early theory held by young children a "vitalist biology".

scientist as an individual that is the 'agent' of scientific activity (see Hoyningen-Huene, 1993). Hence in drawing on Kuhn's ideas to investigate children's knowledge acquisition, Carey is appealing to terms and criteria that were originally formulated to account for social processes of change in the institution of science.

The result of this situation is that a Kuhnian account of scientific development will demonstrate limitations in its application to the growth of knowledge in children. Some of these limitations placed on child-as-scientist considerations were outlined above, regarding the failure of revolutionary descriptions of scientific change to accurately capture the path of knowledge development in children. An even bigger failing in my view is the absence of any clues as to the methods by which children generate, develop, and appraise their knowledge construction efforts. Despite an unorthodox interpretation by Giere (1988), on which he examines Kuhn's ideas from a cognitive individualist stance, Kuhn's focus was not on the representational capacities and judgement strategies utilised by scientists to advance knowledge. Hence by drawing on Kuhn's theoretical framework to investigate knowledge change in children, we are unable to satisfactorily consider the process responsible for this change.

In fairness to Carey, her concern in employing Kuhn's general theory of science is to detail a description of knowledge development in children, not an explanatory theory of learning which she views as a later task, or at the very most one that proceeds in tandem with attempts to describe the content of children's knowledge. However as both Karmiloff-Smith (1992) and Hooker (1987) point out, how you describe development will greatly influence the subsequent perception of 'process'. Nowhere is this better seen than in the science education arena, where Kuhnian inspired descriptions of conceptual change in children have directed the recent wave of intervention programs that attempt to precipitate learning by adopting what has been broadly termed a 'confrontational approach'. On this approach children's intuitive theories of the world are brought into collision with the accepted models dictated by science as a way of promoting conceptual change. However because researchers are working from an account of scientific development which neglects the individual, there is little in the way of illumination as to how children as individual cognitive agents could effect change in such situations.[27] My suggestion is that in looking to science to obtain a valuable perspective on knowledge acquisition in children, we should be

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[27] Particularly misleading in this regard has been Kuhn's early use of perceptual metaphors in his descriptions of revolutionary change. Although later discarded, the idea of change as akin to a gestalt switch has tended to promote the view that conceptual change is a relatively abrupt occurance, as opposed to a gradual process occuring via an extended period of construction.

drawing on an account of scientific inquiry that provides some understanding of the methodological processes by which scientists advance knowledge of the world. The inability of the history of science comparisons considered here to satisfy this demand, indicates an alternative approach to formulating the child-as-scientist metaphor is needed. Such an approach I suggest, will demonstrate a central concern with realist methodology.

4.2 Abductive Explanatory Inferentialism: a methodological perspective on the child-as-scientist debate

In considering the ways in which the child is like a scientist, developmental researchers with the notable exception of Karmiloff-Smith have tended to show little regard for methodological comparisons. For example Wellman (1990) one of the primary advocates for the theory view of children's psychological understanding, dismisses the idea of parallels between children and scientists in terms of the process by which they develop knowledge of the world. Deanna Kuhn (1989) takes an even stronger stand against process analogies. In her view, formulating the child-as-scientist metaphor at the methodological level is not only unhelpful, it serves to promote a fundamentally *misleading* construal of commonsense learning. In Chapter 1, I diagnosed this reluctance to embrace methodological considerations as the result of researchers working off an inappropriate empiricist model of scientific rationality. As indicated, such a model customarily employs the hypothetico-deductive account of scientific method, according to which science is primarily a matter of testing theories for their evidential adequacy. In promoting the view that scientific inquiry can be characterised solely in terms of logic and testing however, HD has been shown to be a seriously deficient theory of scientific method, that not only distances scientific reasoning from the everyday knowledge seeking endeavours of children, but also fails to capture the reality of scientific practice itself. When we discard HD orthodoxy for a more realistic conception of scientific inquiry, it would appear that there is considerable promise in adopting a methodological perspective on the child-as-scientist debate.

In drafting my proposal that child-scientist relations are best explored at the methodological level, I turn to recent developments in scientific realist methodology, in particular a general theory of scientific method proposed by Brian Haig (Haig, 1987; 1995). Entitled "Abductive Explanatory Inferentialism" (hereafter AEI), this account of method takes scientifc inquiry to be broadly speaking a *problem focused endeavour*, which (as indicated by the title) is predominantly concerned with the *abductive generation of theories and their appraisal through inference to the best explanation.*

Mindful that ENR's appeal to a realistic framework for obtaining valuable knowledge demands an account capable of promoting the development of substantive theory, and well aware of the woeful deficiencies of HD doctrine in this regard, Haig looks to articulate a systematic approach to theory building which gives serious attention to the developmental history of a theory.[28] The result is a *wholistic* account of scientific method which, contrary to hypothetico-deductivism's 'blinkered' concern with testing for empirical adequacy, embraces the process of knowledge construction in its entirety; from the formulation of the research problem, and the collection and analysis of data, to the abductive generation of theory, its elaboration via the application of suitable models, and finally its appraisal in accordance with principles of explanatory coherence.

In marked contrast to the received view of scientific method to which children's knowledge construction efforts have been compared by critics of the child-as-scientist metaphor (e.g. D. Kuhn, 1989), AEI offers researchers interested in child-scientist relations a far more realistic portrayal of the knowledge development process, that is adequate both to the demands placed on us by our evolutionary circumstances as well as to the reality of scientific practice. In addition to these twin virtues, it is clear that AEI has not been developed to function as a 'production line' account of theory building. In explicitly rejecting the received view of scientific method as a logical algorithm for extracting truth, Haig is not concerned to supplant it with an equally definitive and hence simplistic equation for theorising. Rather, AEI functions as a broad conceptual framework that attempts to capture how we typically fashion knowledge of the world, thereby holding the potential to illuminate knowledge development in both scientific and everyday contexts.

In this final section a preliminary attempt will be made to refocus the child-as-scientist metaphor at the methodological level, by calling on this general theory of scientific method as an appropriate standpoint from which to compare the knowledge construction efforts of children and scientists. Following this line of reasoning I will firstly look to provide a fuller characterisation of AEI method, and in so doing demonstrate its superiority to HD orthodoxy, before returning to Karmiloff-Smith's work on children's problem solving to illustrate the potential

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[28] Haig has elsewhere described AEI as "a method for theories in the making" (Haig, 1987).

utility of this realist perspective on method in illuminating the process of learning in childhood.

4.2.1 Problem formulation

In looking to outline a realistic theory of scientific method, Haig (1987, 1995) emphasizes the importance of viewing method within the context of problem solving, and contends that an investigation is often set in motion by a poorly structured problem which is then developed through the course of inquiry. This 'problem-oriented' conception of research contrasts markedly with the path of inquiry prescribed by HD method, on which talk of problems is neglected and where the research process proper is seen to open and conclude with the testing of hypotheses for evidential adequacy. These two features of HD method: a disregard for problems and their orienting potential for inquiry and a focus on theory testing, can in fact be seen to be related, since in dealing exclusively with the justification of knowledge claims HD method confines itself to the endpoint of scientific research and fails to broach the issue of how inquiry proceeds towards this goal state. If however the concern is to provide an adequate theory of *method* as opposed to merely a justificationary account of the products of research, then questions concerning the possibility of inquiry and how to provide for its effective regulation necessarily come to the fore. And it is here that a well developed theory of problems can provide the necessary illumination (Nickles, 1981).

Accordingly, in looking to tackle these questions Haig (1987) following Nickles (1981) advances what he terms a "constraint composition" account of problems. On this account a problem is seen to be comprised of all the constraints that are required for its solution, as well as the demand that the solution be found (Haig, 1987). This characterisation pivots on two important realisations:
i) problems are not divorced from background theory or from constraints imposed by empirical data etc; rather these conceptual and empirical constraints are included in the problem itself, and serve to determine its structure.
ii) a problem by virtue of its very nature is necessarily connected to the demands/goals of the research program in which it arises.

Defining a problem in this way, i.e. in terms of the constraints it places on its own solution, enables us to comprehend how inquiry can effectively proceed. Because in articulating the problem we are essentially articulating the constraints on what would count as an admissible solution, the problem itself can be seen to regulate inquiry by directing progress towards its own solution. As both Nickles (1981) and Haig (1987) point out, in describing the problem we are literally halfway to solving it. Hence by housing a constraint composition account of problems within AEI method, Haig gains the necessary skeleton upon which to build a regulative methodology.

Conceptualising problems as 'the directors' of scientific inquiry, is also in line with the aim oriented conception of rationality articulated by Hooker (1987), according to which science is seen to be properly concerned with the pursuit of valuable knowledge, broadly conceived as that which enables us to solve our most pressing problems of living (see also Maxwell, 1985). On this view, problem selection will be based on needs, with the 'weighting' of the problem being a direct measure of the importance placed on solving the problem for our collective survival. And since our most pressing problems will typically be poorly structured in terms of lacking the constraints that are required for their solution, Haig contends that it is the fundamental task of scientific inquiry to improve the structure of our research problems by building in the necessary constraints as inquiry proceeds (Haig, 1995). This last point, which recognises that structuring the research problem will generally occupy an extended time period, further serves to emphasise the regulative power of a constraint composition account of problems for scientific endeavour. For in adopting this view, we realise that problem formulation is not an initial step of inquiry that is executed and then forgotton about. Rather, the research problem extends right through the inquiry process, directing inquiry by pointing the way to its own solution and hence setting the parameters on our theorising as we move through the multiple contexts of theory generation, development, and appraisal that comprise AEI method.

4.2.2 Data collection and analysis

Guided then by a developing problem that serves to direct inquiry by imposing a series of constraints on the knowledge development process, AEI method looks to the collection and analysis of data. This is a necessarily early and as Haig (1987) emphasises very important phase of inquiry, since in endorsing a 'data to theory' move and in recognising theory generation as a valid methodological context, our data collection and analytic efforts effectively lay the groundwork for the theorising process that is to follow. As Haig points out, on AEI method it is the data patterns thrown up by our investigations that act as the "launching pad" for the generation of new explanatory theories (Haig, 1987).

This role in theory generation necessitates that an importance be placed on exploratory data analytic work in scientific inquiry, in addition to the traditional concern resulting from HD's stress on testing with confirmatory data analysis (Tukey, 1980). In Tukey's view, data exploration is usefully conceived as detective work, where the researcher is engaged in an extensive and detailed analysis of the data, casting her collection net widely and employing multiple forms of description, to achieve the richest information yield possible. In order that research may proceed, it is also necessary that the data patterns detected during exploratory data analysis receive some approximate confirmation as to their reliability. Accordingly AEI method takes data analysis as properly comprising a *two stage process,* where patterns detected in the data via exploratory activities, are then checked for their reliability through the application of confirmatory data analysis procedures.[29]

4.2.3 Theory generation

Once the data patterns thrown up by exploratory procedures have been provisionally checked, an attempt is made to obtain some initial understanding of the patterning that has come to light by generating an appropriate explanatory theory. In looking to capitalise on our natural talents for making sense of phenomena, AEI construes theory generation to occur through an abductive reasoning process which involves reasoning back from puzzling phenomena to generate an explanation of the causes underlying the phenomena. Haig (1995) characterises the moves involved in abductive inference in the following manner:

"Some observations (better, phenomena) are encountered which are surprising because they do not follow from any accepted hypothesis; we come to notice that those observations (phenomena) would follow as a matter of course from the truth of a new hypothesis in conjunction with accepted auxiliary claims; we therefore conclude that the new hypothesis is plausible and thus deserves to be seriously entertained and further invesitigated" (Haig 1995 p.9).

In connection with this depiction of abduction, Haig draws attention to a number of regulative principles which can be seen to operate by constraining our

[29] It would seem prudent to emphasise that data are collected and analysed with an eye to extracting robust data patterns or phenomena from the data; hence our theories are generated to explain and predict phenomena, not data. This distinction between between phenomena and data has been subject to neglect in the methodological literature, however as Haig (1995) emphasises it is an important one to make since it serves to acknowledge the proper objects for scientific inquiry.

abductive inferences, thereby ensuring that as researchers we generate theories that provide the most *plausible* explanations of the phenomena under investigation.

By removing HD's ban on 'discovery' activities and admitting theory generation into the scope of science proper, AEI method succeeds in illuminating much more of the process of knowledge development in science than is typically dealt with under the received view of scientific method. Most significantly, by delimiting methodological attention to the business of theory testing, HD method fails to recognise that patterns of reasoning responsible for theory generation exist which are strongly suggestive of a logic or rationality to discovery. By drawing on AEI as our methodological framework in contrast, we are well placed to give attention to these patterns of reasoning, and hence provide some initial demonstration that the process of theory generation can be conceived as a rational affair deserving of further research attention.[30]

In admitting a logic to discovery, AEI stops short of the assumption embodied in naive inductivism, that we can algorithmically generate the correct theory from our data. Rather our natural talents for abduction constrained by various appropriate regulative principles are more likely to result in the provision of a number of plausible explanatory candidates requiring further investigation. For this reason Haig (1987) characterises the logic embodied in abduction as one of "pursuit" as opposed to acceptance, and stresses the necessity of embracing a "thorough going pluralism" in our theory creation efforts.

4.2.4 Theory development

While HD conceives theory generation as properly located outside of science, the methodological process of theory development on this received view of scientific method, is ignored altogether. The fact that HD takes theory testing to be the leaping off point for scientific method, has done much to promote the assumption that theories arise for consideration in a mature form. Assuming that theories are typically ripe for testing however, shows little regard for their developmental nature and has resulted in a situation where low grade theories

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[30] As was indicated in Chapter 1, one of the predominant reasons that HD fails to provide a methodological characterisation of theory generation, viewing it as an activity beyond rational characterisation, is that it operates with a restrictive model of scientific reasoning defined exclusively in terms of formal logics. Not labouring under such a narrow construal of rationality, AEI has the capacity to characterise the seemingly indescribable 'creative leap' as a "discursive reasoning complex" that centres on our natural ability for abduction - a form of inference important to both everyday and scientific inquiry (Haig, 1987).

are prematurely submitted to the testing ground, with little in the way of valuable knowledge being gained by our research efforts.[31]

This undesirable state of affairs is all the more disconcerting when we reflect on Hooker's (1987) comments regarding our evolutionary circumstances. To re-emphasise the point made in Chapter 1, once we recognise that we have no independent access to the world, all the responsibility for obtaining knowledge of what exists in the world necessarily falls to our theorising attempts. If these efforts amount to submitting grossly underdeveloped knowledge claims to empirical test, then our need for constructing substantive theory is not met. It seems clear then that if we are to give serious attention to the aim of relieving our ignorance, a concerted attempt to develop our knowledge claims becomes a crucial component of any rational strategy for advancing knowledge.

Haig (1987, 1995) recognises this necessity for theory development and subsequently accords it a central place in his general theory of method. On AEI the primitive construals afforded by our abductively generated theories are seen to be in serious need of further elaboration, and this is achieved primarily through the application of suitable models. Harre (1976, 1978) in a detailed account of models and their role in science, demonstrates how a model as a representative device can effect the development of a more informative characterisation of a theory's underlying causal mechanisms. The creative task according to Harre, is to invent a plausible analogue of the mechanism which is really producing the phenomenon. An analogue of the primitively understood causal mechanism is developed by drawing on an appropriate source, which is usually well known and understood. Constraints embodied in the process, namely the fact that the mechanism must behave analogously in relevant respects to the known source, and the recognition that the model must maintain a relation with the real processes and patterns of nature, function to discipline the scientific imagination and hence promote an improved formulation of the scientific theory under consideration (Harre, 1976).

In scientific inquiry theories are typically elaborated by exploiting what have been termed "iconic paramorph" models. Iconic models contrast with sentential models in that they provide the researcher with a concrete visualisable image and hence are often useful for representing the theoretical or unobservable entities under investigation. Paramorphs as opposed to homeomorphs have a

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[31] See Meehl (1978) for a damning attack on the "slow progress of soft psychology", which he attributes to social science researchers forgoing attempts to develop substantive theory for the ritualised practice of statistical significance testing.

different source and subject, and therefore are usefully employed in the development of nascent theories where the causal mechanisms are only primitively understood.

4.2.5 Theory appraisal

From the outline given above, it is obvious that AEI provides a greatly expanded view of the knowledge construction process than that dished up by the generally received HD account of science. Not only is theory generation brought in from the cold to be given a genuine methodological status, but attention is drawn to the developmental nature of theories and hence the need for processes such as modelling capable of promoting their elaboration, to be incorporated into the research process. This 'expansion' to methodological orthodoxy undertaken by AEI continues its march into the context of theory appraisal, where HD's singular concern with testing for evidental adequacy is replaced by a multi-criterial perspective on theory evaluation.

As Haig (1987, 1995) points out, the underdetermination of a theory by empirical evidence, conjoined with the recognition that scientific inquiry pursues multiple goals, requires that other criteria in addition to that of empirical adequacy be drawn on to evaluate a theory's worth. Criteria recommending themselves for consideration include consilience, explanatory depth, fertility, and simplicity. Looking to provide a coherent view of theory appraisal sensitive to this need for evaluation over and above simply empirical adequacy, AEI promotes an evaluative framework that forgoes foundational justification for a concern with inference to the best explanation. Within this framework, theory evaluation is a comparative affair whereby competing theoretical alternatives are assessed relative to each other on multiple dimensions in order to determine which provides the *best* explanation of the phenomena under investigation. Such an approach accords both with the general intuition that it is better to have some representational 'handle' on the world than none at all, and with the recognition by ENR that in our attempts to know the world, we are primarily concerned with explanatory understanding.

Recently this idea of inference to the best explanation has been given a precise formulation by Thagard (1989; 1992), in terms of *explanatory coherence.* On this formulation the question of what amounts to the best explanation from a choice of theoretical candidates is decided on the basis of three criteria that serve to reflect the explanatory coherence of a theory; these being consilience, simplicity, and analogy. In Thagard's view, a theory is more explanatorily coherent and hence provides a better explanation of the phenomena under investigation than its opponents if it explains more, requires fewer ad hoc hypotheses to achieve this end, and is consistent with currently accepted theories that explain similar phenomena. Subsequent implementation of this theory of explanatory coherence into a computer program and its successful application to a number of cases of scientific reasoning, lend further credence to Thagard's formulation of inference to the best explanation as a suitable justificationary framework for scientific theories.

From the outline sketched above, I think it is readily apparent that AEI method constitutes a far more adequate framework for scientific inquiry than the reigning hypothetico deductive account on which critics of the child-as-scientist metaphor (e.g. D. Kuhn) have based their claims. By demonstrating an explicit concern with the multiple contexts of theory generation, development, and appraisal, and by deploying a rich account of problems within this methodological space, AEI offers us a broader conception of the knowledge development process that is more successful than its HD rival at explaining how inquiry is possible and providing for its effective regulation. In addition, its capacity as a *general* theory of scientific method means that AEI provides a framework or 'methodological superstructure' within which to situate and better comprehend the myriad specific methods employed by scientists in their daily research. On this view, research methods such as exploratory data analysis (Tukey, 1980), iconic modelling strategies (Harre, 1976), and explanatory coherence methods (Thagard, 1989), are reconceived as *submethods* of the parent mehod AEI. This in turn facilitates a better understanding of both the particular roles these methods play in developing knowledge, and how they can be successfully integrated into a comprehensive research program for science. HD with its preoccupation with testing and subsequent neglect of all other aspects of inquiry, is clearly ill equipped to serve such an integrative function.

Finally, in presenting an adequate strategy for developing valuable knowledge of the world, AEI dispenses with the orthodox conception of the ideally rational scientist who operates by applying the rules of formal logic to the objective facts. Adopting ENR as our philosophical framework, demands that in looking to develop an appropriate account of scientific inquiry we reject the view of method as a logical algorithm for extracting truth and embrace a more realistic model of rationality, consonant with our fallible nature and the demands placed on us by our evolutionary circumstances.[32] Accordingly on AEI, scientists are seen to advance knowledge by abductively generating theories to explain puzzling phenomena, elaborating these initial 'educated guesses' through reasoning by analogy to appropriate source models, and appraising their theoretical efforts in terms of their explanatory power, simplicity, and what is known about similar causal entities in the world. Hence in detailing a descriptively and normatively adequate perspective on scientific method, Haig offers us an account on which it is plausible to suggest substantial correspondences between the knowledge construction efforts of children and scientists. By developing what is essentially a comprehensive theory of theory building, Haig is acknowledging that scientists are not primarily embroiled in logic and testing pursuits as the received view of science would have it. Rather they are by necessity first and foremost theory builders, centrally concerned with the task of generating explanatory theories in order to obtain a representational grip on the world. My contention is that this description is also true of children's problem solving endeavours, and hence by refocusing the child-as-scientist metaphor with the aid of AEI at the methodological level, we stand to gain a valuable perspective on the process of learning in childhood.

4.2.6 Realist methodology, children and scientists: breaking down the barriers

"The tendency to explain phenomena by a unified theory, the most general or simplest one possible, appears to be a natural aspect of the creative process both for the child and the scientist". (Karmiloff-Smith & Inhelder, 1974/5)

In her 1988 article entitled 'The child is a theoretician, not an inductivist', Karmiloff-Smith is concerned to detail how it is that children learn about the world. As a way of tackling this question she describes a number of experimental situations devised by herself and her coworkers, in which children are presented with tasks which they are then required to solve (e.g. building toy railway circuits, block balancing etc). By way of building hypotheses and counter-hypotheses into the problem situation, she attempts to comprehend the strategies children utilise in their discovery of how the physical world functions, and as seen in Chapter 3, identifies the following complex of recurrent interrelated phases in children's problem solving attempts:

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[32] Although HD and naive inductivism are otherwise very different accounts of scientific method, their underlying commitments to empiricism result in both accounts demonstrating a formalistic approach to knowledge making, whereby knowledge is taken to be the assured product of logic + data.

- Children are initially 'data-driven', and achieve behavioural mastery of the task in hand by focusing on information in the external environment. For example, in block balancing tasks children were observed to begin by concentrating on proprioceptive information, with each block being treated as a new task.

- From this success children move to generate a theory to achieve some explanatory understanding of the task they are involved in. Karmiloff-Smith details how children went beyond the goal of successfully balancing the blocks to spontaneously generate a "geometric-centre theory in action", by focusing on their internal representations and ignoring or discarding data that refused to conform to their newly developed theory (e.g. unevenly weighted blocks were rejected as "impossible to balance").

- During the subsequent phase, data and theory are brought back into alignment. In the block balancing task, children were observed to have recourse to a consolidated and generalised theoretical framework which they used to take environmental feedback into account and finally achieve a successful balancing of all the blocks.

From these findings Karmiloff-Smith concludes that in their everyday problem solving endeavours children are not concerned with collecting facts as an inductivist might; rather, like scientists they are guided in their actions by powerful theories, which they construct to obtain an explanatory understanding of the world around them.

In developing this theoretical position on the process of learning in childhood, Karmiloff-Smith looks to substantiate her comparisons of children and scientists by adopting two principal strategies:

i) detailing the operation of an age independent mechanism in cognitive systems which makes theory building possible, thereby overturning the claim (highlighted in Chapter 3), that theory construction is a strategy available only to meta-conceptually aware scientists.
ii) contrasting both scientists' and children's knowledge construction efforts with a naive inductivist view of inquiry (the orienting focus of her 1988 paper).

It should now be obvious that I am in essential agreement with Karmiloff-Smith's claim that the child is a spontaneous theoretician. However what I suggest could further substantiate her assessment of children's problem solving, is an adequate theory of scientific method on which to ground her claims, that gives serious attention to the conception of science as a theory building endeavour.[33] I further think that AEI with its explicit focus on theory generation, development, and appraisal is such a theory, and suggest that adopting it as a standpoint from which to compare the knowledge construction efforts of children and scientists adds further force to Karmiloff-Smith's claim that the process by which children and scientists go about exploring the world is comparable and substantially the same.

To see the potential utility of AEI in this role, consider first the compelling similarities between Karmiloff-Smith's phase model of development which she reconstructs from a microdevelopmental analysis of children's problem solving activities, and the realistic account of scientific method advanced on AEI. In attempting to pinpoint equivalence of children's discovery methods over a wide range of domains, Karmiloff-Smith proposes an account of developmental change which is centrally concerned with the *generation of explanatory theory.* On this account, Karmiloff-Smith explicitly endorses a *data to theory move* in children's knowledge construction efforts and in a similar manner to the path of inquiry mapped out by AEI, suggests that such knowledge construction *proceeds through a number of related phases:*

i) children as natural inquirers demonstrate an initial concern with data.
ii) move to a concern with theory (organisation oriented) - look to a single theory to account for a variety of different phenomena.
iii) coordination of data and theory - the two are reconciled as the newly consolidated and generalised theoretical framework affords children an explanatory understanding of the problem domain.

Within this process oriented theoretical framework, Karmiloff-Smith characterises the generative move as broadly *abductive* in character, whereby children are seen to work back from the patterns of block balancing encountered in the initial phase to postulate a theory that explains these data patterns (i.e. that objects in the world balance at their geometric centre). Further, in examining the ways in which children build up their conceptual explanations, Karmiloff-Smith emphasises the importance of *heuristics* together with other *modelling strategies* in their problem solving. In her studies children were observed consciously

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[33] It is instructive here to note that Karmiloff-Smith (1988) recognises the need for an accurate perspective on knowledge construction in science for her developmental research program, and briefly considers T. S. Kuhn's account of scientific development as a potential candidate. However she rejects it as unsuitable for her purposes and for much the same reason I outlined earlier - because it is concerned primarily with the social process of change in the scientific community rather than with the theory building activities of individual cognitive agents.

employing these strategies as promising search paths to develop their understanding of the causal entities at work, and thereby obtain a better representational handle on the conceptual domain. Significantly, during this phase children were found to be so focused on developing their explanatory theories that they deliberately set empirical disconfirmation to one side, and when pressed by the researcher some children even went as far as to invent observable data, in order to maintain their theoretical commitments. As Karmiloff-Smith points out, children seem decidedly unwilling to attend to any potential counter evidence until they are in possession of a well consolidated theoretical framework. Finally, while not giving explicit attention to theory appraisal, Karmiloff-Smith denys that it is simply success at the task which is the primary motivation behind children's problem solving. As she makes clear, if children were merely success oriented they would conclude their explorations in the initial phase. Yet they go beyond this phase to spontaneously restructure their knowledge base in the search for *explanatory understanding*. Hence in settling on a consolidated and generalised framework in the third phase, Karmiloff-Smith implies that for children as for scientists it is the explanatory power of the theory in hand which satisfies children that they have reached an effective problem solution.[34]

From the points highlighted above, it is apparent that there are some substantial correspondences between Karmiloff-Smith's phase model of the process of knowledge development in children, and the realistic strategy for scientific development articulated by Haig (1987, 1995). Such correspondences in turn suggest that AEI as an adequate theory of scientific method will also demonstrate application in everyday contexts. In adopting Hooker's ENR perspective on science which takes science to be a refined outgrowth of our everyday attempts to comprehend the world, we are led to anticipate continuity between science and commonsense at the methodological level. Given that this expectation seems to be borne out by the child-scientist relations considered above, I suggest we are warranted to draw on AEI as a comprehensive theory of theory building to further extend Karmiloff-Smith's characterisation of the child as a spontaneous theoretician. Of the advantages gained from bringing AEI to bear on questions surrounding the process of learning in children, the following would seem especially pertinent.

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[34] Significantly, in a recent study which <u>did</u> give explicit attention to theory appraisal (Samarapungavan, 1992), children as young as 7 years of age were found to employ explanatory coherence considerations as a basis for choosing between competing theories. Children demonstrated a preference for theories that explained more, required fewer ad hoc hypotheses to achieve this end, and were consistent both internally and with the evidence presented; suggesting that children in a similar manner to scientists can adopt a multi-criterial perspective on theory evaluation.

In the first instance, by importing this general theory of scientific method into the developmental arena, researchers stand to gain a valuable perspective on specific methods or strategies utilised by children in terms of the particular roles these methods play in developing knowledge. To take one example, Karmiloff-Smith (1988) in attempting to characterise the ways in which children learn about the world, stresses the centrality of heuristics to childhood discovery. On an empiricist tradition where knowledge is presented as the product of logic-data interactions, heuristics are not important to scientific inquiry and hence a potentially informative link between children and scientists is not made. On a realist account of science in contrast, heuristics comprise a central component of methodology. Because of our fallible nature and the inherent complexity of the world, these rules of thumb are seen to provide researchers with the most appropriate tools for the task of reducing the complexity of the real world systems under study (see Wimsatt, 1986). Karmiloff-Smith of course rejects logicism as an accurate portrayal of the way in which scientists typically reason and points to the use of symmetry as an explicit heuristic in mineralogy to support her process oriented comparisons of children and scientists. By adopting AEI as our methodological framework I suggest that we are well placed to further Karmiloff-Smith's claim that heuristics provide a realistic strategy for advancing knowledge, and hence point to the appropriateness of children's reliance on these 'weak methods' in their knowledge seeking endeavours.

More generally, AEI not only has the capacity to illuminate specific methods employed by children, but as it does in science this general theory of scientific method can also serve an integrative function, providing a methodological framework within which to situate the specific strategies utilised by children in their everyday attempts to comprehend the world. Examining the literature on children's problem solving it would appear that by in large developmentalists have employed a 'piecemeal' approach in their investigations, according to which individual abilities such as the young child's capacity for induction (Gelman & Markman, 1986), or their ability to test empirical hypotheses (Sodian et al, 1991), have been singled out for attention and detailed study. By drawing on AEI as a methodological framework to integrate the many strategies examined in this way, researchers gain the advantage of a theoretical tool that enables them to consider the process of knowledge development in its entirety. I perceive Karmiloff-Smith to have intitiated this program, by drawing children's strategies together under the umbrella of 'theory-building'. My suggestion is that AEI provides us with the 'theoretical muscle' required to develop this initial characterisation into a comprehensive theory of learning.

Conclusion

"Overall it appears that the reasoning processes of scientists have been idealised and that children's reasoning processes have been undervalued, but that a reanalysis of these positions shows a strong degree of convergence on the position that both the child and the scientist are rational theory constructors . . . " (Brewer & Samarapungavan, 1991).

In recent years, a growing number of psychologists have set aside Piagetian stage-wise descriptions of development, in favour of drawing parallels between conceptual development in children and the growth of knowledge in science. In looking to science to obtain a valuable perspective on cognitive development, the metaphor of the child as an intuitive scientist has captured research attention as a profitable way in which to conceptualise children's interaction with the world and their development of knowledge. However while the metaphor itself has been widely cited, the assumption that important parallels exist between science and commonsense on which the metaphor depends, has not been subjected to concerted appraisal and development. The aim of this study has been to rectify this situation by undertaking a detailed evaluation of these proposed parallels, and in so doing, demonstrate the utility of the child-as-scientist metaphor for developmental inquiry.

In accordance with this aim, the primary tasks for this study were twofold:
i) to settle on appropriate characterisations of both science and commonsense, in order to be in a position to assess the plausibility of the child-as-scientist metaphor;
ii) having substantiated the metaphor, to look at ways to further develop comparisons between children and scientists so that a fruitful characterisation of knowledge acquisition in childhood might be achieved.

Chapters 1, 2 and 3 were concerned with the first of these tasks. In Chapter 1, attention was drawn to the nature of science and the necessity of establishing an appropriate scientific framework with which to assess the rationality of childhood thought. Despite the need for a balanced treatment of both sides of the analogy, a review of the developmental literature revealed that science has typically assumed a fixed incontrovertible position in the child-as-scientist debate, with its validity as an appropriate standard of rationality going largely unquestioned. The fact that science forms the comparative base for assessments of children's thought however, demands that any serious analysis of the child-as-scientist metaphor necessarily incorporates an evaluation of the scientific standards invoked.

Undertaking such an evaluation, it was concluded that an empiricist account of science has dominated assessments of the scientific nature of children's thought, and because of their commitment to this received view of science, very few researchers have been willing to credit the young child with the rationality of the scientist. In its attempt to restrict science to the facts and logic however, empiricism was shown to have been soundly criticised for its inability to capture the reality of scientific practice. By appealing to contemporary commentary in the philosophy of science, an attempt was made to highlight some of the more notable deficiencies inherent in this philosophical framework, and in calling attention to these deficiencies, demonstrate its unsuitability for the role of scientific standard in the child-as-scientist debate. Having rejected the scientific framework that underlies much of the child-as-scientist literature, attention was focused on setting up an appropriate philosophical alternative. Evolutionary Naturalistic Realism was adopted for this role as the best theory of scientific endeavour currently available. In marked contrast to an empiricist account, this radical reinterpretation of science was shown to give serious attention to both our evolutionary circumstances in the world and to actual scientific practice, and hence was endorsed as a normatively and descriptively adequate framework for examining the relationship between science and commonsense.

Having settled on an appropriate scientific framework for exploring child-scientist parallels, Chapter 2 turned its attention to the commonsense side of the analogy, in an effort to establish an appropriate characterisation of everyday thought. This chapter was taken to be a necessary preliminary to developing child-scientist comparisons, since in order to argue that theoretical knowledge is common to both children and scientists, the theoretical status of everyday cognition must first be demonstrated. This was achieved by focusing on our folk psychological model for understanding human action and reviewing claims put forward in the philosophy of mind literature that it fails to constitute a genuine empirical theory. In response to the first challenge raised by a number of researchers that folk psychology does not function in the way that theories function in science, a counter argument was mounted, suggesting that their reluctance to endorse the theory view stems from an inappropriately narrow rendering of theory, underwritten by a commitment to an empiricist philosophy of science. Working from a realistic perspective on scientific inquiry, it was concluded that folk psychology constitutes a commonsense theoretical framework, whose status as a theory is warranted by its explanatory and predictive success in the everyday domain in which it functions.

In response to the second dominant challenge to the theory account which takes the form of an alternative 'simulation' view of our psychological understanding, questions were raised regarding the explanatory power of simulation theory in accounting for our ability to comprehend human action. It was concluded that our species' capacity for simulation in no way challenges the theory view of folk psychology, since simulation is neither necessary nor sufficient for understanding others in the absence of a theoretical framework. Rather than a distinctively different kind of understanding, folk psychology was revealed to be essentially the same sort of understanding as our knowledge of the rest of the world, achieved through a process of informed trial and error guesswork.

Having set up an appropriate theoretical framework for exploring child-scientist parallels, the focus in Chapter 3 moved to young children's knowledge and the extent to which comparisons could be made between the young child and the scientist. Drawing on children's developing knowledge of the mind as a case study, findings were highlighted which served both to challenge the traditional depiction of the child as an inferior thinker and provide some compelling evidence in support of the child-as-scientist metaphor. Specifically, by tracing the child's developing understanding of the causes of human action, it was argued that the child could be seen as an intuitive scientist in two important ways; firstly with regard to the content of their knowledge, and secondly in terms of the process by which such knowledge undergoes development. In light of these findings, the reluctance by some researchers to endorse child-scientist comparisons was diagnosed not as a true reflection of the developmental situation, but rather as a manifestation of persistent beliefs concerning deficiencies in the child's cognitive machinery, coupled with an adherence to an empiricist model of what it is to do science. In contrast, by advocating a realistic account of scientific inquiry, and by outlining current developmental theory which indicates that the young child has the capacity for cognitively flexible thought, the child-as-scientist metaphor was seen to be upheld as a profitable way in which to conceptualise the growth of knowledge in childhood.

With the plausibility of the child-as-scientist metaphor established, Chapter 4 turned its attention to the second major task outlined for this study, namely to develop the metaphor with a view to achieving a valuable perspective on knowledge acquisition in childhood. Accordingly, the chapter began by examining how child-scientist relations have been developed to date, in terms of parallels between the growth of knowledge in children and the growth of knowledge in the history of science. Undertaking a critical evaluation of these existing approaches, it was concluded that formulating the analogy in terms of comparisons with the history of science exhibits a number of limitations, not least the neglect of methodological questions concerning the processes by which children and scientists develop their knowledge in everyday and scientific contexts.

In light of these limitations, it was deemed necessary to draft an alternative formulation of the child-as-scientist metaphor, on which it was argued that a focus on the methods of inquiry utilised by children informed by a realist perspective on science, constitutes the most profitable approach to developing the analogy between science and commonsense. An abductive theory of scientific method consistent with Evolutionary Naturalistic Realism was outlined for this purpose, and compelling similarities between children's methods of inquiry and this realistic account of scientific endeavour were highlighted. Given these similarities, it was concluded that the metaphor of the child as an intuitive scientist with 'science' understood in realist terms, does provide researchers with an informative characterisation of cognitive development, and by refocussing the metaphor at the methodological level, researchers stand to gain a valuable theoretical tool for developmental inquiry.

In conclusion, the goal of this study has been to demonstrate the utility of the child-as-scientist metaphor for advancing scientific understanding of the processes by which children learn about the world. This has been achieved by undertaking a detailed examination of both sides of the analogy, in order to establish appropriate characterisations of both scientific inquiry and children's commonsense thought. In stripping science of its positivist empiricist cloak in favour of a realistic perspective on scientific endeavour, and by drawing attention to current psychological research suggesting that the child is a spontaneous theoretician, this study has argued that the child-as-scientist metaphor should be upheld as a plausible metaphor for developmental inquiry to pursue. By outlining a comprehensive theory of scientific method and drawing attention to compelling similarities between children's problem solving and the process of knowledge development in science, some preliminary methodological directives have been provided regarding how such a research program might best proceed.

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